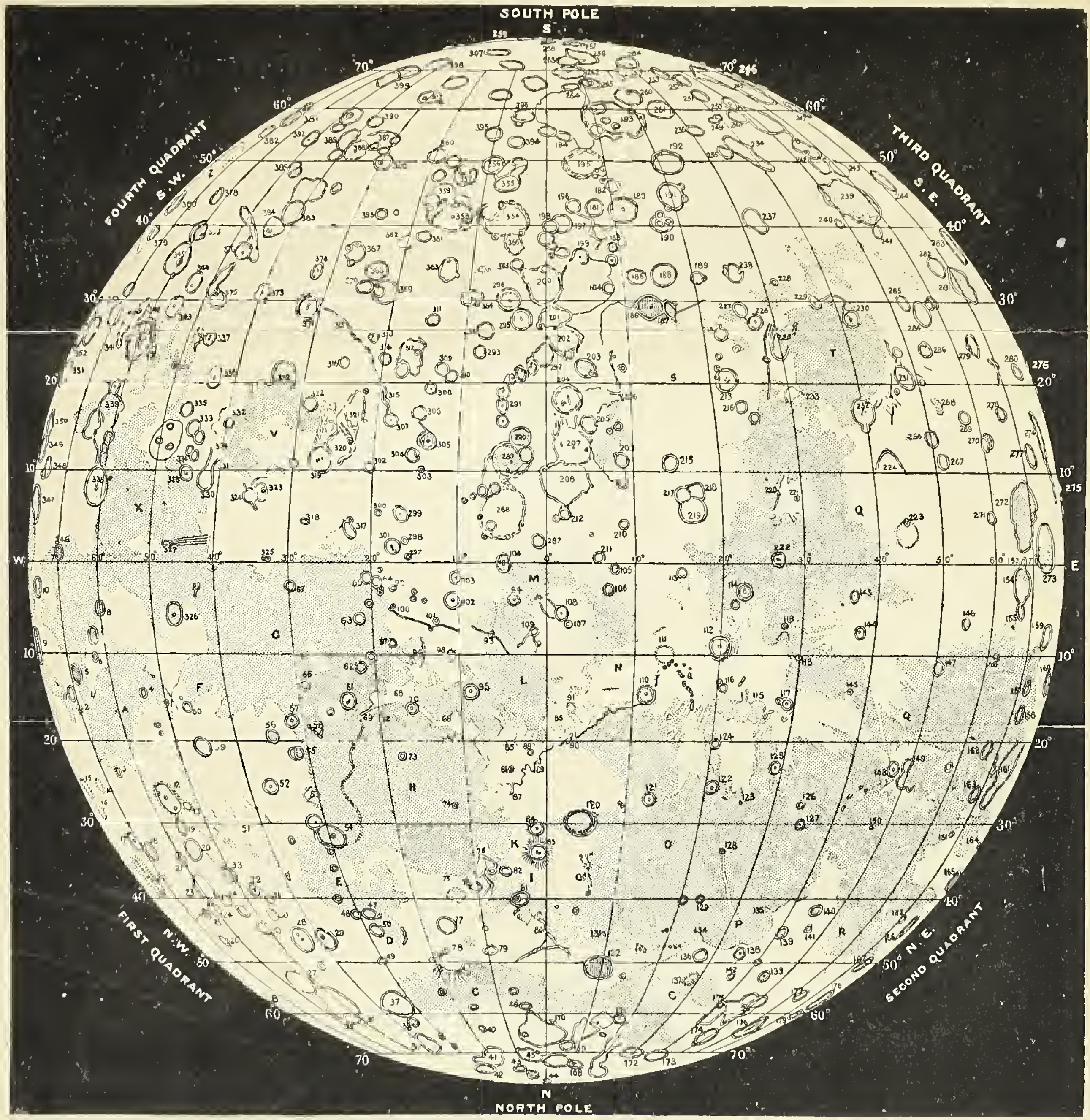
HOURS

WITH A THREE-INCH

TELESCOPE

CAPT. WM. NOBLE, F.R.A.S., F.R.G.S.

[*Frontispiece.*



MAP OF THE MOON.

HOURS WITH A 3-INCH TELESCOPE

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TELESCOPE

BY

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PREFACE.

The following pages are, to a large extent, a reprint of a series of papers which, at the request of my friend Mr. Proctor, I wrote for the columns of 'Knowledge,' in which they originally appeared. The work in its collected form simply aims at being a primer of the Three-inch Telescope, and is designed to instruct the very beginner in the use of an instrument of that size, mounted on a common table stand and unprovided with any means of finding objects in the sky by means of their co-ordinates. The reader is further supposed to know no more of the constellations than may be learned from 'The Stars in their Seasons,' which forms one of the series of the 'Knowledge Library.' In one sense, every single line in the book is original ; inasmuch as every object referred to was actually described and drawn by myself, at the eye end of a telescope of three inches aperture. One thing I must most earnestly disclaim, and that is anything in the shape of competition or rivalry with any existing work treating of telescopic observation. My highest aspiration will be fulfilled if this little book should serve as an introduction to, and induce the amateur

diligently to study, a work the charm of whose style is only equalled by the scientific value of its contents : I mean, of course, the 'Celestial Objects for Common Telescopes' of the late lamented Prebendary Webb. I should be proud indeed to feel that my unpretending rudimentary lessons had been the means of introducing the student to that treasure-house of the glories and beauties of the heavens, and should appreciate such a result as the highest reward that I could receive for the pains and trouble I have taken.

CONTENTS.

HOURS

WITH

A THREE-INCH TELESCOPE.

CHAPTER I.

THE INSTRUMENT.

THIS little book is written to furnish the very beginner in observational astronomy with such directions as shall enable him to employ, to the greatest possible advantage, the kind of instrument with which he will, in all probability, at first provide himself. For, be it noted in the outset, it is not intended for the possessors of telescopes of considerable aperture equatorially mounted or furnished with elaborate rackwork movements in altitude and azimuth.[1] For the owners of such an abundant literature is already in existence; and they have, at present, such admirable works as Webb's 'Celestial Objects for Common Telescopes,' Crossley, Gledhill, and Wilson's 'Handbook of Double Stars,' Chambers's one-volume edition of Smyth's 'Celestial Cycle,' &c. I shall presuppose nothing on the part of the reader, then, beyond an ardent desire to become familiar with the beauties and glories of the celestial vault; and trust, if I can secure his attention, to put him fairly in the way of gratifying such a

[1] These terms will be explained as I proceed.

high and laudable aspiration. To this end I shall take as my text the maps in the volume entitled 'The Stars in their Seasons,' which forms one of the 'Knowledge Library' series. I should also recommend the student to possess himself of the smaller Star Atlas by Mr. Proctor, as well.

As it is of the first importance that the workman should be familiar with the tools he has to use, I propose to begin with a description of the telescope itself, which I will imagine to be a three-inch achromatic one, of about forty-two inches focal length, mounted upon an ordinary 'pillar-and-claw' stand. Such an instrument, as usually sold, is shown in fig. 1, which, however, represents it as furnished with a valuable little subsidiary contrivance (to be immediately described) that the observer will have to make (or to get made) himself. And here, albeit I am earnestly anxious to eliminate the commercial element altogether from consideration, I am compelled to caution the student against supposing that a first-class three-inch telescope can be made for 5*l.*, or, in fact, for any sum approaching it. The object-glass alone must cost the maker something like this amount. Hence, as I propose to deal with and describe celestial objects, as seen in an instrument of the highest class, I give this preliminary warning, lest the young observer should spend his money on a cheap glass, and then wonder at the discrepancy between the delineations of stars and planets in the following pages, and his own views of them. There is a vast amount of rubbish vended in the shape of (so-called) cheap telescopes, and no tyro should ever purchase such a one without its previous examination and testing by a skilled expert. Makers like Cooke, Dallmeyer, Grubb, and Wray, will not imperil their great and deserved reputation by selling an inferior object-glass even to a total stranger : but instruments of unknown opticians require the most rigid trial before they can be safely bought. I shall give, further on, a few tests by which the student himself may judge somewhat of the quality of an instrument he may propose to

purchase. It is time, however, to turn to our figure below. Here we see the brass tube T, into one end of which screws the cell containing the object-glass O. Through a tube projecting from the brass disc which covers the other end of T, the smaller tube S is worked in and out by the milled head F, acting on a rack and pinion. This is for the purpose of focussing the telescope, and making the image of the object observed sharp and distinct. Into the tube S screws the eye-piece E, consisting of two lenses mounted in a short piece of tubing. Shortly, the action of the instrument is

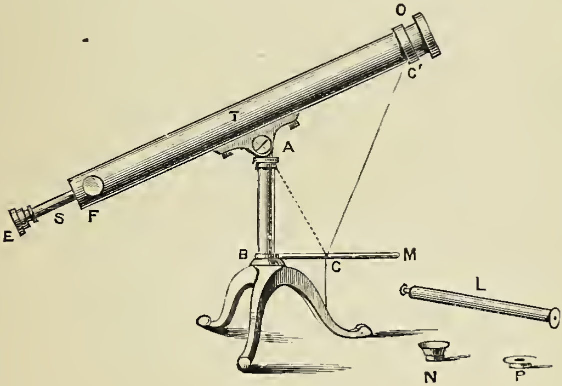

Fig. 1.

this. The object-glass forms in its focus an image of the object to which it is directed, and the eye-piece—which is really a microscope—magnifies this image before it enters the observer's eye. So much for the telescope itself. It is bolted, as will be seen, by two screws and nuts, to a brass plate, which has a vertical motion by means of the knuckle-joint at A, at the top of the stout brass pillar A B, and a horizontal one, furnished by the rotation of the whole of this top, fitting inside the pillar. Three massive feet form its support. The arm B M, shown in the drawing, forms no part of the ordinary fitting of the instrument ; it constitutes the subsidiary contrivance of which I spoke above, and I

shall explain its use presently. L in the figure represents a terrestrial, or four-lens eye-piece, which shows objects erect, and hence is used for land purposes. It screws in at the extremity S, just as E does. The ordinary astronomical, or so-called 'Huyghenian' eye-piece, contains, as I have previously said, only two lenses, and inverts, or turns objects upside down. This, however, is obviously immaterial in a star; and this construction of the eye-piece enables us to obtain high magnifying power with comparatively small loss of light. N is another astronomical eye-piece, and P a dark glass cap or shade, screwing on to every eye-piece for the purpose of observing the sun. The student is earnestly warned never to look at the sun through a telescope without first covering the eye-piece with one of these shades. When, however, I come in the succeeding chapter to speak of the sun, I shall describe how the solar details may be telescopically shown without looking through the instrument at all. The powers usually supplied with a telescope of the size I am describing, are one terrestrial one, magnifying, perhaps, forty-five diameters; and three astronomical ones, giving powers of something like 50, 100, and 180. If, however, its possessor intends to devote his instrument wholly to celestial observation, I should advise him to replace the terrestrial eye-piece by two Huyghenian ones, magnifying twenty-five (for comets, nebulæ, and clusters) and 250 (for close double stars) respectively. For night use, too, a 'dew-cap' will be found indispensable. This may be made of a tin tube, bright outside and blackened within, about eight inches long, and fitting over the end of the telescope at O. This prevents direct radiation from the object-glass itself, and the consequent deposition of dew upon it. *Never wipe your object-glass if you can possibly help it.* Expose it to the heat of a fire (not too near) or of next morning's sun should it become heavily dewed.

A word may now be said as to the use of the bar B M shown in our sketch. It is a fact familiar to nearly everyone who has ever opened an Astronomical Primer (and, at any rate,

to be established by a single winter night's observation of the sky from dusk to dawn), that the stars all seem to describe circles round a centre in the northern sky, called the pole, very close to which is situated the star we call the pole-star. The farther we go from this centre, the larger these circles become, up to a distance of 90° ; beyond which they begin to diminish again. Moreover, the point round which they turn is in this country something over 50° above the northern horizon (depending on the observer's latitude), so that they are all described obliquely to the horizon. Obviously, were the apparent axis of the concave celestial vault vertical, the pole would be overhead, and the stars, seeming to describe circles parallel to the horizon, would neither rise nor set. In this imaginary condition of things (imaginary in England, but it really exists at the poles), the mounting of the telescope shown in the figure above would enable the observer to follow a star by merely turning the telescope round the vertical axis A B, when once that star was in the field of view ; but a moment's thought will show that a simple movement round a perpendicular axis will by no means accomplish this when the star's path is described round an inclined one. The vertical movement of the telescope, I may here say, is spoken of as its motion in altitude ; its horizontal motion as that in azimuth. It will require a little more attention to see that if we so tilted the axis A B that it became parallel to (or practically coincided with) the apparent axis of the sky, then the simple motion round it would cause the telescope to follow any star to which it was directed, from its rising to its setting. A telescope thus placed is said to be equatorially mounted. Now the little device in the cut, for which, in its existing form, we are indebted to the Earl of Crawford and Balcarres, is intended to communicate an approximately equatorial motion to the object end of a telescope mounted as above, on an ordinary altazimuth stand. It takes the form of a bar B M, extending from the base of the pillar A B. In it, at such a distance from the point B, vertically under A, that the angle A C B shall be equal to the latitude of the place

of observation, a hole is bored, and a thumb-screw (shown at C) inserted through the bar, so as to nip a light chain or thin wire tight, when it is passed through the hole. The other end of this chain is fastened anywhere towards the end of the telescope at C′, and sufficient weight is put on to the eye end of the telescope to keep the chain or wire C C′ tight. Perhaps I may say that if (as is very common) the height from A to B is 11 inches, the hole at C may be $8\frac{3}{4}$ inches from B. This will give a quasi-equatorial movement to the telescope for London, and for places not differing much from it in latitude. The use of this contrivance is very simple. The bar B M is placed due north and south (the end M of course being towards the south). A star is got into the field, and the chain C C′ stretched tight and made fast. Then the observer will find that in rotating the telescope horizontally round A, the end O will be so shackled as to constrain it to follow the given object.

A few miscellaneous hints may conclude what I have to say on the telescope itself. First the reader may wish to test it for its freedom from colour and aberration. For the first let him turn the instrument on to the 'limb' (or round edge) of the moon, and first move the eye-piece within the focus by means of the milled head F: then a purple fringe should appear on the lunar limb. On moving the eye-piece outside the focus, this should give place to a green fringe; a telescope that exhibits this sequence of phenomena

Fig. 2.

Fig. 3.

is achromatic. For spherical aberration, focus the telescope on a tolerably bright star with the whole aperture, and then

put a diaphragm of, say, $1\frac{1}{2}$ inch aperture over the object-glass, and see if the star remains accurately in focus. If it does, spherical aberration is cured too. A bright star in focus with a power of 150 should present the appearance of fig. 2, and by no means that of fig. 3, which latter indicates a practically worthless object-glass. Nor should any illuminated *haze* appear about bright stars or planets. Presuming that the instrument acquired by the student whom I am addressing has been found equal to these tests, he may proceed to put it to practical use. The first object to which it shall be directed is the sun, and to this our next chapter shall be devoted.

CHAPTER II.

THE SUN.

In connection with the observations we are about to attempt, it is necessary to reiterate and emphasise the caution given on p. 4. On no account then, whatever, must the observer attempt to look at the sun under the same instrumental conditions that he would employ in viewing the stars. To try to do so without either the interposition of a dark-coloured eye-glass, or the employment of a device to be immediately explained, is almost certain to involve permanent blindness altogether. Sir William Herschel lost an eye in such an attempt; an attempt against which I earnestly warn the student. As a matter of practice, however, opticians send out each astronomical or Huyghenian eye-piece with a dark-glass cap, which must be screwed on whenever the sun is to be looked at directly through the telescope. Should the purchaser of an instrument have his choice of colour in these eye-caps I would recommend very dark green or blue, or else what is known as 'London smoke,' as the most agreeable tints for use. Red glasses are less liable to crack with the sun's heat, but they are by no means so pleasant to look through. Whatever colour, however, the observer selects, let him take care that it is dark enough; and as dark glasses are, as I have hinted, liable to crack with the sun's heat, means must be taken to diminish that heat as much as possible. This will involve, though, one of two things: either the cutting down of the aperture of the instrument to two inches, or even less, if

the observation is likely to be a protracted one; or the turning away the object-glass from the sun at short intervals should the whole of the object-glass be employed, to give the eye-piece time to cool. There is a device which, should the possessor of a telescope choose to go to the cost of it, enables the sun to be viewed for an almost indefinite period with the whole aperture. It consists simply of a perfectly plane plate of glass placed at an angle of 45° with the axis of the telescope, so as to reflect the image formed by the objective in a direction square to the optical axis. The outside of this plate is ground, so as to destroy any secondary reflection; and, pretty obviously, a very large proportion indeed both of the sun's light and heat passes through it. The small amount which is reflected passes into an ordinary Huyghenian eye-piece (which may now be covered with a lighter eye-shade), which must itself be obviously placed at right angles to the optical axis of the telescope. Or, finally, we may view the sun without looking *through* our telescope at all; and, for getting a general idea of solar detail, the method I am about to describe is perhaps the best of all. Moreover, it enables half-a-dozen people to view the solar disc at once, if necessary. In this way of using the telescope we convert it into a kind of solar microscope or magic-lantern, and throw the sun's image on to a sheet of very fine, clean, hot-pressed cardboard, which we shift to and from the eye-piece, and move the focussing tube until a sharp and distinct image of the sun is obtained. It will be necessary to have a large sheet of pasteboard covered with black paper, through a hole in the middle of which the eye-piece comes, in order to shield the card on which the image is projected from direct sunlight. The same end would be more perfectly attained by passing the object end of the telescope through an aperture in the shutter of a completely darkened room; but this is rather too elaborate an arrangement for the ordinary observer. Where only one person wishes to see the sun at a time, the receiving disc may be fastened at the bottom of a paste-

board cone fitting over the eye end of the telescope, and with an aperture cut in the side to look through. An arrangement of this sort is illustrated on p. 136 of the 'Lessons in Elementary Astronomy,' by the editor of 'Knowledge,' published by Messrs. Longman. Whichever of these ways we select to view the sun in, we shall be struck by three or four salient features of his surface. The first thing we shall note is that the limb or edge of the sun is perceptibly darker than the middle of his disc, which gradually shades off as we approach his circular outline. The effect of rotundity which this gives to his image is very striking. A little consideration will show that this must be the effect of an atmosphere surrounding what is technically called the photosphere, or light-radiating surface of the sun. The next thing that will arrest our attention—perhaps just now [1] the first—will be the dark spots which diversify the sun's face.

Fig. 4.—Spot on Sun, Sept. 12, 1883, 11.25 a.m.

The above figure may serve as an illustration of an individual single spot, and was drawn with a power of 80, on Wednesday, September 12, 1883, at 11.25 a.m. It will be seen to consist of two well-distinguished parts, a dark interior one, known technically as the umbra (three of these umbræ at least will be observed to be included in the penumbra in the sketch above), surrounded by a lighter fringing which is called the penumbra. By the use of a peculiarly constructed eye-piece, and a telescope of considerable aperture, the late Mr. Dawes discovered black spots within all large umbræ, and even some small ones. If the observer knows exactly what to look for, he may sometimes pick these up even with a three-inch telescope. It will, however, be necessary to cover the diaphragm in the eye-piece with a circular disc of glazed visiting card (with the glazed side

[1] This was written in 1883, when a sun spot maximum was approaching.

towards the field glass), centrally perforated with a minute hole made with a fine red-hot needle. The telescope is moved until the spot occupies this exceedingly circumscribed field; and thus cut off from the surrounding glare, the nucleus may often be detected. I have so far spoken as though spots were isolated, but they perhaps most frequently appear in groups, involving the most enormous areas on the sun's surface, of the disturbances of which they are the outward and visible sign.

Our next figure represents a group of spots visible on the sun at 9.50 a.m. on June 30th of the same year, and was drawn (as in the case of every other figure which appears in these pages) at the telescope. As a reflecting eye-piece was used in this particular case, though, everything is turned right for left in the engraving. It will be noted how the curves of the penumbræ connected the umbræ. Micrometrical measurement made immediately after our sketch gave the superficial area of the left-hand group as 762,940,200 square miles, and that of the right-hand one 1,074,370,000 square miles, or in all 1,837,310,200 square miles of the sun's surface, as involved in this stupendous disturbance alone! It could be seen with the naked eye when defended by a darkened or smoked glass. There were other spots on the sun's disc at the time. Careful study of the spots under the most favourable definition will reveal certain striking features. The umbræ, under ordinary circumstances, seem to be black; but the student who has the opportunity of watching a partial solar eclipse, or a transit of Mercury, will at once be struck with the extreme blackness of the moon's

Fig. 5.—Group of Spots, June 30, 1883, 9 50 a.m. (visible to the naked eye).

limb or of the planet, as contrasted with the (now, by contrast) brown hue of the spots. A distinctly brown and even orange tinge may often be seen in the images of spots projected on to a sheet of cardboard in the manner described above. Attentive study of the penumbra will reveal a kind of fimbriated or fringed appearance in it; and it will be further noticed to be darkest at its outer edge, and seemingly to get lighter as it approaches the umbra. Returning now to the limb or edge of the sun—which, as I have previously said, will be perceived to be notably darker than the centre of his disc—we shall find the shading diversified by curious and often rather complicated streaks of light. These are called 'faculæ,' and are most numerous and conspicuous about spots which are close to the limb, or where such spots are about to break out. I have sometimes traced faculæ for some considerable distance on to the brighter part of the sun's disc; but, as a rule, they are only seen near the limb. The accompanying sketch represents a group of faculæ which was visible on the morning of August 25th, 1883, at 9 h. 40 min.

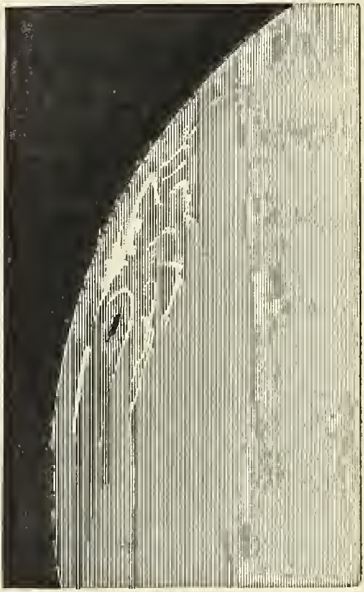
Fig. 6.—Faculæ on Sun's limb, Aug. 25, 1883, 9.40 a.m.

It was drawn on the paper on to which the image of the sun was projected, in the manner previously described.

The fourth piece of solar detail of which I need here speak is the mottling or graining of his surface. This is best caught by shifting the telescope a little, so as to make the sun's image move about in the field. If this be done, the eye will soon receive the impression of a roughness or grain upon the sun's face, akin to that of a piece of magnified loaf-sugar. In large instruments this is seen under the best definition to consist of markings which have, not unaptly, been compared to rice grains, but its resolution into these appearances is wholly beyond our instrumental power.

Such are the leading features observable on the surface of the sun with the means at our disposal. I may say, however, with reference to them, that I am not writing a heliographical treatise; and hence, for their interpretation, must refer the reader to 'The Sun,' by Mr. R. A. Proctor, or to the volume of the 'International Scientific Series' bearing the same title, by Professor Young. I have simply essayed—not, I trust, wholly without success—to indicate what may be seen upon the sun in a three-inch telescope. By the aid of Browning's star spectroscope, with a very narrow slit, the spectra of prominences (those huge uprushes of hydrogen gas known as the 'red flames' which are seen during a total solar eclipse) may often be detected on the sun's limb, even in a telescope of the size of that whose use is presupposed; but the mention of the fact must suffice here.

CHAPTER III.

THE MOON.

Of the moon I shall treat somewhat more in detail, as, probably, one of the first objects to which the incipient possessor of a telescope will be likely to direct his instrument and attention. But I am not going to write here a complete treatise on selenography. Those of my readers whom I may succeed in interesting sufficiently in this subject will, doubtless, proceed to the section devoted to it in Webb's admirable work, 'Celestial Objects for Common Telescopes,' and to that even more elaborate one, 'The Moon,' by Mr. E. Neison, which may be fairly regarded as a kind of lunar encyclopædia. What I propose to do in these pages is to point out to the possessor of a three-inch telescope exactly what it may be expected to show him in the shape of lunar scenery, and of the general physical conformation of our satellite. To this end I present, in the frontispiece, a map of the moon, founded on the excellent one by Mr. Webb, and which also appears in the volume on 'The Moon,' by Mr. Proctor. I have purposely retained the lettering and numbering adopted by Mr. Webb to facilitate reference, and propose to describe and draw a selection of the objects thus indicated, with the end of familiarising the student with the principal features of the surface of our satellite. Some of the chief of these I have drawn at the telescope, in order that the young observer may know precisely what to look for; and I shall in all cases give the exact age of the moon and the power employed, in order that the sketches so made may be directly

comparable with the moon herself. The map almost explains itself. It gives an inverted image of the moon as it would appear in a telescope with an ordinary Huyghenian eye-piece of low power. The curved lines represent the lines of lunar longitude, the moon being supposed to be in what is called her condition of 'Mean Libration.' The meaning of this phrase (which is, however, not very material for our present purpose) will be found thoroughly explained in the work on 'The Moon,' by the editor of 'Knowledge,' to which I have referred above. One immediate use to which we may put these lines is this. The curve separating the illuminated part of the moon's disc from the dark part (technically called the 'terminator') creeps over her face at the rate of $12° 11' 26{\cdot}7''$ per diem. Hence, when she is one day old, the central part of this arc will be in lunar longitude $77° 48' 33{\cdot}3''$ east of her centre; at two days old, at longitude $65° 37' 6{\cdot}6''$ east; and so on until she is 7·38 days old, when she will be 'dichotomised,' or exactly half light and half dark. So far the bright crescent is concave towards the east. Afterwards, when the moon has entered her 'first quarter,' the 'terminator' becomes convex towards the east. and continues to increase in convexity until full moon, when it merges in the moon's general circular outline. Pretty obviously these phenomena recur in reverse order between the time of full moon and that of her becoming 'new' again. Suppose, now, that the student wishes to know what formations are near to the boundary of light and darkness when the moon is 5 days old. $5 \times 12° 11' 26{\cdot}7'' = 60° 57' 13{\cdot}5''$, the longitude of the terminator from the west limb. Taking this from 90°, we find $29° 2' 46{\cdot}5''$ as its longitude from the moon's centre; and now, looking at the map, we see that while the craters and ring plains 374, 371, 372, 323, 57, 48, 37, &c., will all be illuminated (albeit very obliquely), the sun will not yet have risen on 367, 321, 320, 319, 318, 47, and 50, and only partially on 54. In like manner, the position of the terminator at any other age of the moon may be determined.

In fact, my chief object in introducing these lines of longitude at all is to supply the beginner with the means of ascertaining with sufficient accuracy when any given formation is most favourably placed for observation, and incidentally of identifying it. When once he is familiar with the leading features of the lunar surface, he will easily be able to determine for himself the times at which they can be most advantageously examined. If we reflect for a little, it will be seen that this must evidently be when the object under examination is most obliquely illuminated—in other words, when it is tolerably near to the boundary line between light and darkness. Suppose that we had to determine the shape of a white basin at a distance of a couple of miles, with a pocket telescope, at night, and had our choice as to the method of illuminating it. Obviously we should not cast the light of a lantern directly into it—or we should perceive nothing but a circular white patch in the telescope. We should light it from the side ; the shadows which it would in consequence cast revealing its contour distinctly. Now, at full moon the sun is (for our present purpose) shining vertically on to our satellite, which, consequently, presents nothing but a mottled, spotted, and shaded surface, the most conspicuous features being certain dark patches, erroneously named 'seas,' and a radiating series of streaks issuing from a crater (hereafter to be described), called Tycho, situated, in an inverting telescope, towards the top of the moon. People with keen vision can detect this system of streaks with the naked eye ; when so seen, though, they, of course, seem to radiate from the southern part, or *bottom*, of the moon. With these preliminary remarks, I may proceed to furnish a key to the map forming the frontispiece. I merely give the names of the various formations here, reserving any description of them individually until I come to treat of their aspect in the telescope. Beginning, then, with the chief dark markings or patches :—

A, Sea of Conflicts. B, Humboldt's Sea. C, Sea of Cold. D, Lake of Death. E, Lake of Dreams. F, the Marsh of a Dream.

G, the Sea of Tranquillity. H, the Sea of Serenity. I, the Marsh of Clouds. K, the Marsh of Corruption. L, Sea of Vapour. M, Middle Bay. N, Bay of Heat. O, Sea of Showers. P, Bay of Rainbows. Q, Ocean of Storms. R, Bay of Dew. S, Sea of Clouds. T, Sea of Moisture. V, Sea of Nectar. X, Sea of Fertility. Y, Smyth's Sea. Z, the South Sea.

RING-PLAINS, CRATERS, MOUNTAIN RANGES, &c.

1. Promontorium Agarum
2. Alhazen
3. Eimmart
4. Picard
5. Condorcet
6. Auzout
7. Firmicus
8. Apollonius
9. Napier
10. Schubert
11. Hansen
12. Cleomedes
13. Tralles
14. Oriani
15. Plutarch
16. Seneca
17. Hahn
18. Berosus
19. Burckhardt
20. Geminus
21. Bernouilli
22. Gauss
23. Messala
24. Schumacher
25. Struve
26. Mercury
27. Endymion
28. Atlas
29. Hercules
30. Oersted
31. Cepheus
32. Franklin
33. Berzelius
34. Hooke
35. Strabo
6. Thales
37. Gärtner
38. Democritus
39. Arnold
40. Christn. Mayer
41. Meton
42. Euctemon
43. Scoresby
44. Gioja
45. Barrow
46. Archytas
47. Plana
48. Mason
49. Baily
50. Burg
51. Mount Taurus
52. Römer
53. Le Monnier
54. Posidonius
55. Littrow
56. Maraldi
57. Vitruvius
58. Mount Argæus
59. Macrobius
60. Proclus
61. Pliny
62. Ross
63. Arago
64. Ritter
65. Sabine
66. Jansen
67. Maskelyne
68. Mount Hæmus
69. Promontorium Acherusia
70. Menelaus
71. Sulpicius Gallus
72. Taquet
73. Bessel
74. Linné
75. Mount Caucasus
76. Calippus
77. Eudoxus
78. Aristotle
79. Egede
80. Alps
81. Cassini
82. Theætetus
83. Aristillus
84. Autolycus
85. Apennines
86. Aratus
87. Mount Hadley
88. Conon
89. Mount Bradley
90. Mount Huyghens
91. Marco Polo
92. Mount Wolf
93. Hyginus
94. Triesnecker
95. Manilius
96. Julius Cæsar
97. Sosigenes
98. Boscovich
99. Dionysius

100. Ariadæus
101. Silberschlag
102. Agrippa
103. Godin
104. Rhæticus
105. Sömmering
106. Schröter
107. Bope
108. Pallas
109. Ukert
110. Eratosthenes
111. Stadius
112. Copernicus
113. Gambart
114. Reinhold
115. Carpathian Mts.
116. Gay Lussac
117. Tobias Mayer
118. Milichius
119. Hortensius
120. Archimedes
121. Timocharis
122. Lambert
123. La Hire
124. Pytheas
125. Euler
126. Diophantus
127. Delisle
128. Carlini
129. Helicon
130. Kirch
131. Pico
132. Plato
133. Harpalus
134. La Place
135. Heraclides
136. Maupertuis
137. Condamine
138. Bianchini
139. Sharp
140. Mairan
141. Louville
142. Bouguer
143. Encke
144. Kepler
145. Bessarion
146. Reiner
147. Marius
148. Aristarchus
149. Herodotus
150. Wollaston
151. Lichtenberg
152. Harding
153. Lohrmann
154. Hevelius
155. Cavalerius
156. Galileo
157. Cardan
158. Krafft
159. Olben
160. Vasco de Gama
161. Hercynian Mts.
162. Seleucus
163. Briggs
164. Ulugh Beigh
165. Lavoisier
166. Gerard
167. Repsold
168. Anaxagoras
169. Epigenes
170. Timæus
171. Fontenelle
172. Philolaus
173. Anaximenes
174. Anaximander
175. Horrebow
176. Pythagoras
177. Œnopides
178. Xenophanes
179. Cleostratus
180. Tycho
181. Pictet
182. Street
183. Sasserides
184. Hell
185. Gauricus
186. Pitatus
187. Hesiod
188. Wurzelbauer
189. Cichus
190. Heinsius
191. Wilhelm I.
192. Longomontanus
193. Clavius
194. Deluc
195. Maginus
196. Saussure
197. Orontius
198. Nasir-ed-din
199. Lexell
200. Walter
201. Regiomontanus
202. Purbach
203. Thebit
204. Arzachel
205. Alpetragius
206. Promontorium Ænarium
207. Alphonsus
208. Ptolemy
209. Davy
210. Lalande
211. Mösting
212. Herschel
213. Bullialdus
214. Kies
215. Guericke
216. Lubiniezky
217. Parry
218. Bonpland
219. Fra Mauro
220. Riphæan Mts.
221. Euclid
222. Landsberg
223. Flamsteed
224. Letronne
225. Hippalus
226. Campanus
227. Mercator

228. Ramsden
229. Vitello
230. Doppelmeyer
231. Mersenne
232. Gassendi
233. Agatharchides
234. Schiller
235. Bayer
236. Rost
237. Hainzel
238. Capuanus
239. Schickard
240. Drebbel
241. Lehmann
242. Phocylides
243. Wargentin
244. Inghirami
245. Bailly
246. Dörfel Mts.
247. Hausen
248. Segner
249. Weigel
250. Zuchius
251. Bettinus
252. Kircher
253. Wilson
254. Casatus
255. Klaproth
256. Newton
257. Cabeus
258. Malapert
259. Leibnitz Mts.
260. Blancanus
261. Scheiner
262. Moretus
263. Short
264. Cysatus
265. Gruembergor
266. Billy
267. Hansteen
268. Zupus
269. Fontana
270. Sirsalis
271. Damoiseau
272. Grimaldi
273. Riccioli
274. Cordilleras
275. D'Alembert Mts.
276. Rook Mts.
277. Rocca
278. Crüger
279. Bergius
280. Eichstädt
281. Lagrange
282. Piazzi
283. Bouvard
284. Vieta
285. Fourier.
286. Cavendish
287. Reaumur
288. Hipparchus
289. Albategnius
290. Parrot
291. Airy
292. La Caille
293. Playfair
294. Apianus
295. Werner
296. Aliacensis
297. Theon sen.
298. Theon jun.
299. Taylor
300. Alfraganus
301. Delambre
302. Kant
303. Dollond
304. Des Cartes
305. Abulfeda
306. Almamon
307. Tacitus
308. Geber
309. Azophi
310. Abenezra
311. Pontanus
312. Sacrobosco
313. Pons
314. Fermat
315. Altai Mts.
316. Polybius
317. Hypatia
318. Torricelli
319. Theophilus
320. Cyrillus
321. Catherine
322. Beaumont
323. Isidore
324. Capella
325. Censorinus
326. Taruntius
327. Messier
328. Goclenius
329. Biot
330. Guttemberg
331. Pyrenees
332. Bohnenberger
333. Colombo
334. Magelhaens
335. Cook
336. Santbech
337. Borda
338. Langrenus
339. Vendelinus
340. Petavius
341. Palitzsch
342. Hase
343. Snell
344. Stevinus
345. Furner
346. Maclaurin
347. Kästner
348. La Perouse
349. Ansgarius
350. Behaim
351. Hecatæus
352. Wilhelm Humboldt
353. Legendre
354. Stöfler

355. Licetus	371. Piccolomini	386. Pitiscus
356. Cuvier	372. Fracastorius	387. Hommel
357. Clairant	373. Neander	388. Vlacq
358. Maurolycus	374. Stiborius	389. Rosenberger
359. Barocius	375. Reichenbach	390. Nearchus
360. Bacon	376. Rheita	391. Hagecius
361. Buch	377. Fraunhofer	392. Biela
362. Büsching	378. Vega	393 Nicolai
363. Gemma Frisius	379. Marinus	394. Lilly
364. Poisson	380. Oken	395. Jacobi
365. Nonius	381. Pontécoulant	396. Zach
366. Fernelius	382. Hanno	397. Schomberger
367. Riccius	383. Fabricius	398. Boguslawski
368. Rabbi Levi	384. Metius	399. Boussingault
369. Zagut	385. Steinheil	400. Mutus
370. Lindenau		

The beginner with the telescope who has read or heard of 'mountains' in the moon, and who takes his first look at our satellite with a view of examining them, will certainly be puzzled by the spectacle presented to his gaze. If we suppose the moon to be five or six days old, and that he is regarding her southern horn (or upper one, as seen in the telescope), he will be struck by the fact that it seems to be completely honeycombed by circular or elliptical holes, surrounded by ridges, their walls breaking into each other, and the depressions themselves being confluent in all directions. A little thought and attention will reveal the fact that these are volcanic craters on the plains, surrounded by cliffs, with, in many cases, conical hills rising from their centre, which we are viewing from above, as though, in fact, we were looking down upon them from the car of a balloon suspended at a tremendous height above them. In the case of those close to the terminator, the sun is just rising, and their depressed plains or cup-shaped interiors are still plunged in the blackness of night; while the more elevated cliffs surrounding them have already caught the sun's rays, and stand prominently out of the darkness. The words 'blackness of night,' which I have just used, are peculiarly appropriate in the case of the moon, inasmuch as,

from her absence of atmosphere, light is not scattered, as it is upon the earth, and everything that is not in brilliant sunshine is in total darkness. The observant student may possibly demur to this statement when he notices that, close to the terminator, the light fades gradually ; but he must bear in mind that the sun is rising very slowly at this part of the moon's surface, and that only a small portion of his disc (from which, moreover, his rays fall very obliquely) is above the horizon there. One notable effect of the absence of air, and the consequent brilliant lights and jet-black shadow son our satellite, is, that telescopic power tells upon her surface to an extent incomparably greater than it does in the case of any other body in the sky. Let us assume that we are employing a power of 160. Well, this shows us the moon as she would appear to the naked eye were she only 1,468 miles from the surface of the earth—a pretty long distance truly; but when we consider that Mont Blanc is discernible by unassisted vision from Lyons, 100 miles off, through all the thickness of the intervening terrestrial atmospheric vapour, we shall gain some notion of what this represents in the case of the airless moon, with her brilliant lights and inky shadows. A power of 250 will bring her seemingly within 939 miles of us: but no useful purpose will be attained by the employment of such magnification (for seleno-graphical purposes) with a three-inch telescope. In our subsequent sketches 160 is the highest power that was ever used. The nature and character of the objects it will reveal will become apparent in the description of them which will follow.

Night One.

In commencing our examination of some of the typical and more remarkable objects on the moon's surface, I will suppose that she is between three and four days old. Arming, then, our three-inch telescope with a power of 120, we proceed to direct it to her face ; and a very remarkable spectacle it is which will present itself to the student making his

maiden observational essay on our satellite. He will first be struck by the number of ring-plains, of which I have briefly spoken above, between the circular bright western limb of the moon and the 'terminator;' by which name, as I have previously explained, the boundary of light and darkness is known. The Sea of Conflicts (A in our map) and part of the Sea of Fertility (X) will also strike his eye. Before proceeding, however, to scrutinise the various objects contained within the bright crescent of the moon, it will be interesting to shift her image in the field of view of the telescope. If this be done, it will be found that the whole of the moon is visible ; the dark limb looking like a very ghost on the black background of the sky. Moreover, if the atmospheric conditions are favourable, a certain amount of detail will be readily seen upon this dark portion of the moon, a bright spot, Aristarchus (148 in our map), and a dark one, Grimaldi (272), being the most conspicuous objects. I may shortly say here, with reference to this phenomenon, that it is the effect of earth-shine. Five minutes' study of the diagram illustrating the changes of the moon which appears in every elementary work on astronomy that has ever been written, will show that when the moon is new to the earth, the earth is full to the moon. Moreover, we present a disc to our satellite more than thirteen times the size of that which she exhibits to us, and hence it will be seen that the amount of light we send her at the time of her conjunction (or when she is 'new') must be very considerable. Of course, as the moon waxes to us, we wane to her, so that it is only during the first and last few days of every lunation that this earth-shine renders the dark side of the moon visible. Having satisfied ourselves as to its visibility, we will return to the illuminated crescent. Now, the craters and plains visible at the time of which I am speaking all present, more or less, an elliptical outline, the ellipticity becoming more and more marked as we approach the bright limb. If the student will regard a terrestrial globe from a little distance, he will at once understand that this is an

effect of perspective. In fact, while the Sea of Conflicts (A) seems to have its major axis north and south, it in reality lies from east to west; this great, dark plain measuring only 281 miles from north to south, and 355 miles from east to west. I have called it a plain, but a little attention will show undulating ridges on parts of its surface. Its greenish grey tint will be noted, too. To the east of this 'sea,' Picard (4) will be seen. To the west of this is a white spot, which is a rather mysterious object, having been seen to present the most varying appearances. North-east of Condorcet (5) is the Promontorium Agarum, a kind of peninsula projecting into the Mare. This is a striking object when the moon is nearly sixteen days old. Cleomedes (12) is a fine formation, about seventy-eight miles in diameter. It has a trifid mountain in its interior. On its eastern wall is situated a very deep crater plain, Tralles (13 in the map). There is a central mountain on the floor of this, too. Endymion (27) is a circular plain (elliptical as it appears in the telescope). Its western wall rises in places to a height of upwards of 15,000 feet. Directing our instrument now towards the southern half of the lunar crescent, we arrive at Langrenus (338) and Vendelinus (339), the former a splendid object, with a bright central hill. And now we come to that grand object, Petavius, which, as illustrating several typical lunar features, I have here drawn.

Fig. 7.—Petavius Moon's Age, 3·24 days.

As seen in a three-inch telescope with a power of 120, the moon's age being 3·24 days, it will be noted how the wall is divided by narrow valleys. The mountain in the convex interior is nearly 5,600 feet high; and from this a straight dark line, or 'rill,' will be seen to extend in a south-easterly direction to the wall. These rills, as they have been called, are very numerous on the moon; but few are so conspicuous as the one of which I am speaking. They appear to be exceedingly deep ravines, clefts, or cracks; but they

are, undoubtedly, the most inexplicable of all lunar objects. Sometimes they pass through wall and plain indifferently; at others, they seem to stop short at an object, but to reappear on the other side of it. Moreover, they occasionally intersect. I shall have more to say of them as I proceed. Before concluding to-night's work, the attention of the young observer may be directed to one or two points of the Leibnitz Mountains (259), just coming into sunlight, and shining like stars close to the southern cusp of the moon.

Night Two.

Our first essay in the examination of the lunar surface was supposed to be made when the moon was between three and four days old. To-night I will imagine that her age has increased, and is about six days. The first thing which will strike the attentive student is the changed aspect, under the more vertical light of the sun, of the formations he has observed at an earlier date in the lunation. Objects near the moon's western limb, which, lit laterally by the rising sun, cast black shadows, and so revealed their configurations distinctly, are now illuminated (like the 'depths of the sea,' in the famous prize poem) by 'the sun's perpendicular rays,' and are converted into mere bright blotches upon a darker background. A strange formation which was close to the terminator at the epoch of our last observation, so curiously illustrates the change of aspect induced by varying illumination, that I give three illustrations of it as seen in the waxing, full, and waning moon at the ages given under the respective drawings. It is numbered 327 in our map, and is called Messier, presumably from its resemblance to a comet; the French astronomer, after whom it is named, having been, as is pretty well known, one of the keenest searchers for and discoverers of comets of the last century.

The two slightly diverging streaks which seem to radiate from the right hand, or eastern of the two craters ('Messier A'), appear almost artificial in their regularity. The most

curious thing, however, in connection with these two craters is this : that Mädler, as the result of a large number of ob-

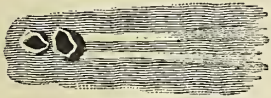

Fig. 8.—Messier. Moon's Age, 3·95 days.

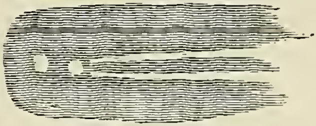

Fig. 9.—Messier. Full Moon.

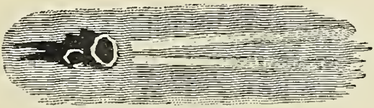

Fig. 10.—Messier. Moon's Age, 17·8 days.

servations, called pointed attention to their precise similarity in size, form, depth, and brightness. A glance at either of our drawings made at the telescope at the epochs specified will suffice to show that they now differ widely in this respect : that Messier itself (the western one) is decidedly smaller than Messier A, and that their major axes lie approximately at right angles to each other. The young observer should try to view this formation under the same illumination as I myself did in making the third of the above sketches ; the long peaked shadows revealing curiously the structure of the crater walls which cast them. Messier itself is about nine miles in diameter. The southern extremity of the Sea of Nectar (V) terminates in a kind of bay, known as Fracastorius (372).

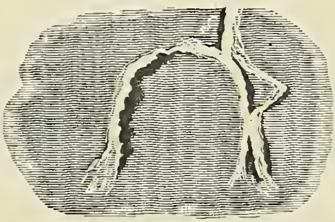

Fig. 11.—Fracastorius. Moon's Age, 5·65 days.

Under this illumination Fracastorius looks like what I have called above a bay. If, however, it be observed when quite close to the terminator (preferably in the waning moon), it will be

seen as a complete circle, the northern part of it consisting of low detached blocks. South of it is a very fine object, the grand ring-plain Piccolomini (371), about $57\frac{1}{2}$ miles in diameter. Between this and Frascastorius the moon is very mountainous. South of Piccolomini lie a number of craters and ring-plains, whose names may be learned from our map. Starting now from the north side of the Sea of Nectar we find an interesting pair of craters, Isidore and Capella (323 and 324); and crossing the Sea of Tranquillity from south to north we arrive at a group of craters, Römer (52), Littrow (55), Maraldi (56), and Vitruvius (57). A little range of mountains of the ordinary terrestrial type, called Mount Argæus (58), will be noted just on the Sea of Tranquillity. On the north-west boundary of the Sea of Serenity (H) lies one of the largest ring-plains in the moon, Posidonius (54), some 62 miles in diameter. There is a fine central crater in this formation, and it would form an instructive exercise for the incipient selenographer who can draw, to try and sketch some of the details which abound in this fine object. Atlas (28) and Hercules (29) here shown are two noble walled plains or depressions, 55 miles and 46 miles broad respectively. It will be noted that while the most conspicuous object in the interior of Atlas is a mountain, in Hercules it is a crater. Glancing at Pliny (61), a fine terraced ring, full of

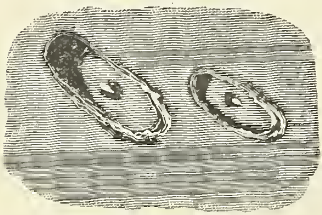

Fig. 12.—Atlas and Hercules. Moon's Age, 5·65 days.

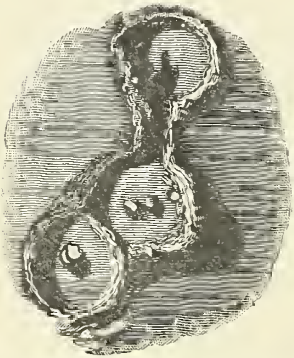

Fig. 13.—Catherine, Cyrillus, and Theophilus. Moon's Age, 5·65 days.

little hills, on our way southward again, we will conclude our night's work by the examination of that noble triple group, Theophilus, Cyrillus, and Catherine (319, 320, 321). The study of the connection between these grand objects and of the way in which they are connected supplies us with a key to the chronology of this part of the lunar surface. The valley connecting Catherine and Cyrillus will be observed, as also the way in which the wall of Cyrillus has been intruded on by Theophilus.

Little or no detail is observable in Catherine when so near the terminator, but the shape of the shadows cast into its interior reveals that of the ridges and peaks causing them. Cyrillus will be seen to be more trapezoidal than circular, and the two mountains in its centre and the conspicuous crater on its wall will at once arrest the eye. Theophilus is the deepest crater in the moon, the walls being in places 18,000 feet above the level of the bottom. Its diameter is nearly 64 miles. Necessarily its sides are brilliantly illuminated by the rising sun when the interior is plunged in the blackest night, and at about the fifth day of the moon's age it may be seen projecting beyond the terminator into the darkness of the seemingly surrounding sky as a brilliant ring. Sharp-sighted people can detect this without any optical aid.

Night Three.

Advancing sunlight is now bringing into view a highly complicated mass of walled plains and craters in the south-western quadrant of the moon; and with some of the more notable among them we will begin our work to-night. Maurolycus (358 in our map) is a splendid object about the time of the moon's first quarter. The great complexity of the wall will attract the attention of the observer. A few crater pits may be detected with the instrument we are employing on the walls, as well as on the floor of Maurolycus, and there are numerous hills on the latter also visible

under favourable illumination. Another splendid object in this neighbourhood is Stöfler (354), but the inside of this is very much more level and undisturbed than that of its neighbour. The system of bright streaks radiating from Tycho (previously referred to on p. 16) passes over this region, with the curious result that the bold and most conspicuous formations of which I am speaking to all intents and purposes disappear at full moon altogether! In Walter (200), Regiomontanus (201), and Purbach (202) we have an instance of three crater plains in connection with each other, and lying, approximately, north and south of each other, one example of which we have already seen in Theophilus, Cyrillus, and Catherine, and another of which we are immediately to examine in Arzachel, Alphonsus, and Ptolemy. North-east of Purbach lies Thebit (203), a crater well worth examining, as attentive inspection will show that another crater has burst the original wall, and has itself in turn been intruded on by a more minute one still. Here, again, we are able to trace the chronological sequence of the successive eruptions. A strange formation, known as 'Straight wall,' but looking (when the moon is eight or nine days old) like a stag's horn on the top of an alpenstock, will be noted not far to the east of Thebit. And now we arrive at that truly superb triple system, Arzachel (204), Alphonsus (207), and Ptolemy (208).

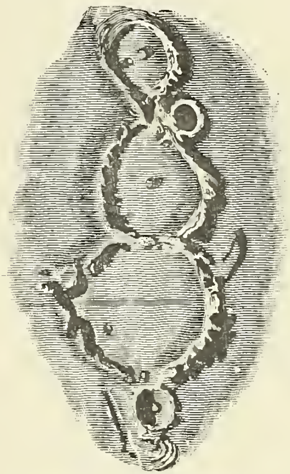

Fig. 14.—Arzachel, Alphonsus, and Ptolemy.

Arzachel is about $65\frac{1}{2}$ miles in diameter, with terraced walls, diversified by clefts and craters. Alphonsus is 83 miles across, and has very complicated walls. The northern one

opens by clefts and valleys into Ptolemy—an enormous walled plain of 115 miles in diameter. The conspicuous crater in its floor will at once strike the eye. In Alphonsus, the chief object in the interior is a mountain; while in Arzachel both a mountain and a crater will be noted by the observer. In our sketch above, Alpetragius (205) will be seen to have its interior wholly immersed in shadow. This beautiful crater is about 27 miles across, and is so comparatively deep as to be only free from shadow for less than a week during the entire lunation. Herschel (212) is a fine ring-plain, 24 miles in diameter, with a central mountain. Rhæticus (104) is noticeable as lying actually on the lunar equator. Godin (103) and Agrippa (102), two ring-plains of 23 and 27 miles in diameter respectively, are fine objects when seen near the terminator. The observer should carefully examine that curious object Hyginus (93) and its neighbourhood about the time of the first quarter, employing for this purpose as high a power as his telescope will bear (say 160). He will note the curious rill running right through the crater, the snail-shaped or spiral mountain just to the north of it, a brilliant ridge to the west of this again, and so on. Hereabouts it is that the alleged discovery of the depression known as 'Hyginus N.' was made. The incipient observer with a three-inch telescope must not, however, blame either himself or his instrument should he fail to distinguish this mysterious object. Manilius (95) is a fine object under proper illumination. Its diameter is 25½ miles. The Sea of Serenity, at which we now arrive (H), contains numerous objects to reward the observer. Among them is the curious one, Linné (74), which, save when almost on the terminator, presents the appearance of a minute whitish cloud, or little smudge of light. It may be found on a line drawn from Pliny (61) through Bessel (73). The two splendid craters, Eudoxus (77) and Aristotle (78) here drawn, present a grand spectacle when near the boundary of light and darkness, either with a waxing or a waning moon. My own sketch on the next page was made

when the sun was rather too high above their horizon. Under suitable illumination Aristotle will be seen to be surrounded by radiating chains of hills. Cassini (81) is a curious object about the time of the moon's first quarter. Its diameter is about 36 miles, and it contains a ring-plain, some nine miles across, within it. The edge of the ring of Cassini must be considerably serrated or cut into peaks and spires. With Archimedes (120), Aristillus (83), and Autolycus (84) we shall conclude our work to-night. The examination of the region in which they are situated may well afford us an entire evening's occupation on a future occasion.

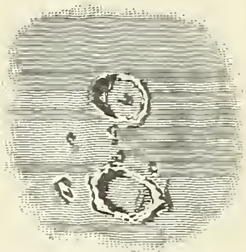

Fig. 15.—Eudoxus and Aristotle.

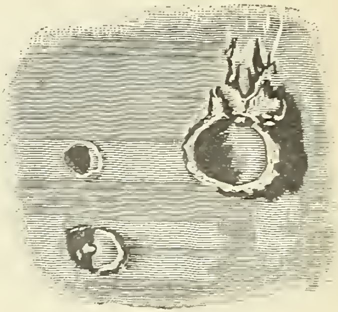

Fig. 16.—Autolycus, Aristillus, and Archimedes.

Archimedes is a comparatively shallow ring-plain of 50 miles in diameter. The inside, with our instrumental means, will appear quite smooth; but powerful telescopes show minute craterlets and spots in it. When, however, this great plain is fully illuminated, a three-inch telescope will show that the floor is striped or streaked with alternate light and darker bands. Archimedes is a grand object when the sun is either rising or setting upon it. Aristillus, 34 miles across, has a central mountain, shown in our sketch. Under rather more oblique illumination, ridges, like lava streams, may be seen radiating from the outer ring. Autolycus, 23 miles in diameter, is tolerably deep, but calls for no more special description here.

Night Four.

To the north-west of Cassini (described on p. 30) lie the Lunar Alps (80 in our map), a range of mountains possessing a much more terrestrial character than the majority of objects visible on the moon's surface. They start from the neighbourhood of Cassini, and extend with a very remarkable interruption, immediately to be spoken of, nearly, if not quite, to Plato. The interruption of which I have just spoken takes the form of an enormous wedge-shaped valley, between eighty and ninety miles long, and varying in width from three and a half to six miles. Our sketch represents this region as it appears with a power of 120, the age of the moon being 7·58 days.

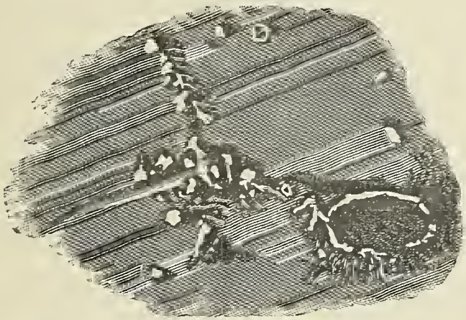

Fig. 17.—The Valley of the Alps, and Sunrise on Plato. Moon's Age, 7·58 days.

The eastern side of the valley is the steeper of the two. The highest of the mountain masses lie to the west of the huge cleft, the eastern range, however, increasing in magnitude as it approaches Plato (132). The sun was just rising on this last-named superb formation at the time the drawing above was made ; and its interior, as will be seen, was plunged in the blackness of night. While scrutinising this part of the moon's surface, the student may direct his attention to the two interesting ring-plains to the north—

Archytas (46) and Timæus (170). Plato itself, and its vicinity, present a most interesting region for examination during the seventh, eighth, ninth, and tenth days of the moon's age; as they do (though at a most inconvenient hour) when she is twenty-one or twenty-two days old. This great walled plain measures sixty miles across, and is notable, when fully illuminated, for its steel-grey tint. Its surrounding wall is broken in places, and exhibits very little of that series of descents in terraces which we shall find by-and-by in Eratosthenes, Copernicus, &c. A variety of streaks and spots have been detected upon the very level floor by the aid of large and powerful telescopes; but by far the larger proportion of these details are hopelessly beyond the reach of the observer with such an instrument as that whose use is presupposed. Under suitable illumination, the shadows of three huge peaks on the western wall will be seen cast upon the floor; as will that of an even higher one from the eastern wall out on to the very broken surface of the Mare beyond. It is, so far, an inexplicable fact, that, as the sun rises on the interior plain of Plato, it follows the usual law of getting brighter until the sun has attained an altitude of 20°, or thereabouts; after which it darkens very notably and perceptibly until shortly after full moon. South of Plato stands that absolutely isolated peak, Pico (131), in the dark grey Sea of Showers. As it is some 8,000 feet in height, it casts a tremendously long shadow under the oblique illumination either of sunrise or sunset, and forms a most conspicuous object. Timocharis (121) is worth looking at for its terraced wall. The glorious mountain chain of the Apennines (85, 87, 92, in our map) presents, like the Alps of which I have spoken above, a very decidedly more terrestrial character than the vast majority of lunar objects. We may regard this superb range as starting in the north from Cape Hadley (87), which rises more than 15,000 feet from the plain at its base, although they will be seen to trend in a south-westerly direction from it. Following them, however, in their eastern course round the Sea of Showers,

we come to Bradley (89), a mountain 13,600 feet in height, and to Huyghens (90), the loftiest of their peaks, attaining an altitude of some 20,000 feet. The spectacle presented by this range of mountains—for the observation of which a power of 160 may be employed on a fine night—with their glittering and corrugated highlands, and the serrated shadows cast by their peaks on the plain beneath, is a wonderfully beautiful one, and will repay the most earnest attention the student can give to it. The projection of this noble ridge beyond the illuminated part of the moon, about the time of first quarter, is easily discernible with the naked eye by moderately sharp-sighted people. It may be held to terminate with Eratosthenes (110), the description of which, however, I must reserve for our succeeding night.

Night Five.

Eratosthenes, of which I spoke at the conclusion of our fourth night's work as terminating the magnificent chain of the lunar Apennines, presents a beautiful spectacle about the ninth day of the moon's age. The accompanying drawing was made with a power of 160, when the moon's age was 9·23 days. The diameter of this finely terraced formation is about thirty-seven and a half miles, and its walls will be seen to be very rugged. The three central peaks, too, are conspicuously shown under this illumination. It is curious that a formation presenting such strongly marked features when lighted obliquely by the rising or setting sun, should be by no means easy to find at full moon. South-east of Eratosthenes will be noted a deep mountain range

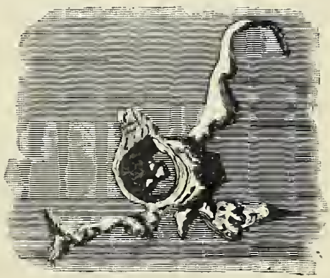

Fig. 18.—Eratosthenes. Moon's Age, 9·23 days.

terminating in a ring-plain, whose walls are only some 130 feet or so high. Hence it is only visible during a short period of favourable illumination, and forms a very severe test of the defining power of a three-inch telescope, and of the keenness of the observer's vision. The height of the connecting ridge of mountains is some 4,470 feet. As Ben Nevis is 4,406 feet, and Snowdon only 3,571 feet high, this may suffice to furnish a scale whereby the student may estimate the dimensions of the leading features of this neighbourhood. Schröter (106), or rather, its northern vicinity, should be carefully looked at when near to the terminator, for the strange system of ramparts sloping off on either side of a central one, which Gruithuisen believed to be artificial, but which, in reality, consists of a series of parallel valleys. Parry (217), Bonpland (218), and Fra Mauro (219) are more or less imperfect ring-plains, which present a curious appearance when pretty near the terminator. Pitatus (186) and Hesiod (187) are a pair of huge craters—or rather ring-plains—connected by a pass. The northern wall of the former will be seen to be imperfect, while the southern wall is separated from Tycho, which we are immediately to examine, by a rugged mass of mountain peaks. The two most notable peculiarities in Hesiod are, a central crater in the floor, and a cleft (shown in our map), running into the Sea of Clouds. And now we arrive at what has been aptly called by the late lamented Prebendary Webb 'the metropolitan crater of the moon,' Tycho (180), reference to the system of streaks emanating from which has been once or twice previously made. This splendid formation, visible as a white spot to the naked eye at full moon, measures fifty-four miles and a quarter across, and exhibits an elaborately terraced wall, some 16,000 feet high, on the east side, and upwards of 17,000 feet in height in its western portion. In fig. 19 I have purposely abstained from any attempt to delineate the extremely disturbed and rugged region surrounding Tycho, confining myself strictly to drawing the crater itself.

The central hill shown below is between 5,000 and 6,000 feet high, its conical shadow being very conspicuous at the time our drawing was made. The inextricable mass of craters, hillocks, pits, and irregularities in the immediate neighbourhood of Tycho, almost defies any attempt to draw or map it. The wonderful system of light-rays, radiating from this great crater, extends over at least a quarter of the visible hemisphere of the moon. Some of them may be traced to the southern limb, and doubtless extend beyond it into that hemisphere which is always hidden from the terrestrial observer. One tremendous ray passes through the Sea of Serenity, the craters 70 and 73 in our map lying upon it. Another very conspicuous one connects Tycho with the interesting formation Bullialdus (213). It is a notable fact, that while these rays, in nearly every other instance, pursue their course through hill, valley, crater, and plain, without deviation or interruption, the crater Saussure (196) has deflected one of them, and caused it apparently to bend round its southern wall. *What* these stupendous bands are, can only be regarded, at present, as a mystery. Nasmyth considers them to be cracks filled up with molten lava from the moon's interior ; but, arguing from their terrestrial analogues, trap-dykes, we should expect to find them projecting, more or less, above parts of the lunar surface, and, as a necessary consequence, casting shadows, when on, or near, the terminator. As a matter of fact we find them everywhere absolutely level with the regions which they traverse. Of whatever material they are composed, its reflective power must be very high, inasmuch as the ray system of Tycho traverses the (in many cases) huge and complicated formations, Sasserides (183), Gauricus (185), Heinsius (190), Wilhelm I. (191), Longomontanus (192),

Fig. 19.—Tycho. Moon's Age, 9·24 days.

Clavius (193), Maginus (195), Orontius (197), Nasir-ed-din (198), Lexell (199), Walter (200), Moretus (262), Stöfler (354), and Maurolycus (358), all of which are most conspicuous objects when obliquely lighted ; but which, one and all, disappear wholly at full moon, or under vertical illumination ! The late Professor Nichol, amid much which, after all, amounted merely to assertion, did point out one valuable piece of evidence furnished by these rays ; and that is, the proof afforded by their continuous visibility, and the homogeneous character of their brightness throughout their course, that the reflective substance of which they are composed is absolutely everywhere uncovered. Did anything in the shape of vegetation, for example, exist in the moon, it must obscure portions of these light streaks. That they pass undimmed, then, from their origin to their termination, shows plainly enough that they traverse 'a rocky desert, devoid of life or living thing.' Here our night's work may cease. We shall turn our telescope on Copernicus (112) as soon as it is favourably illuminated.

Night Six.

When the moon is nine or ten days old, the Bay of Rainbows (P in our map) presents a perfectly charming spectacle to the observer. This great, dark, semicircular area appears absolutely level in the instrument we are using, but is surrounded by a mass of stupendous cliffs. It measures, from Cape La Place (134) to Cape Heraclides (135), nearly 135 miles. Heraclides rises some 4,000 feet above the level of the bay, but is as a mere hillock compared with some of the neighbouring highlands. As we travel in an easterly direction we arrive at Sharp (139), 15,000 feet in height, and some of the peaks in this chain probably attain an altitude approaching to 20,000 feet. Nearly due south of Cape La Place lie two little, but exceedingly deep craters —the eastern one of which, Helicon, is marked 129 in the map. And now we arrive at a region covered with systems

of light-streaks, akin to those described on p. 35 as emanating from Tycho. Euler (125), a fine ring-plain, 19 miles in diameter, with a central peak, is the centre of one of these systems of rays. Tobias Mayer (117), 22 miles across, is an interesting object under suitable illumination. Of all the formations, however, in this region of the lunar surface, there is nothing to compare with that superb one, Copernicus (112), our sketch of which was taken with a power of 160, when the moon's age was 10·27 days. This magnificent ring-plain measures 56 miles across. There are, altogether, eight peaks rising from the interior—three bright ones, and four less so. With the instrument employed, however, and under the conditions of illumination then obtaining, two only of these were, as will be seen, visible at the epoch of our drawing. The terraced character of the wall is conspicuous enough, even in a 3-in. telescope, as is the disturbed and complicated character of the region immediately surrounding it. Two deep craters south of Copernicus, approximating in appearance to the figure 8, will at once strike the eye. So also will a conspicuous peak on the western wall, which is between 11,000 and 12,000 ft. high. The somewhat angular character of the contour of the wall is well seen from the shadows cast towards the east. Other features will strike the attentive observer. At full moon, Copernicus is seen to be the centre of a system of light-streaks, uniting with similar ones from other formations to which we shall hereafter refer. It is worthy of note that the streaks extending in a westerly direction from Copernicus are the most numerous; though those which

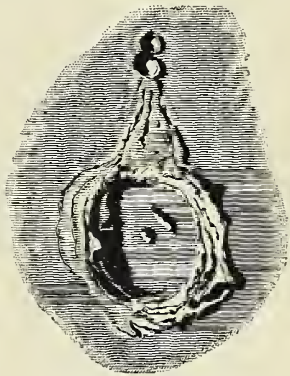

Fig. 20.—Copernicus.
Moon's Age, 10·27 days.

lie towards the north are individually more conspicuous. There is an enormous number of tiny craters between Copernicus and Eratosthenes (110); but even the largest of these require favourable illumination and conditions to be seen in our instrument. Reinhold (114), 31 miles across, will repay scrutiny while the telescope is turned on this part of the moon's visible disc. Euclid (221) and Landsberg (222) furnish examples of craters surrounded by a kind of nimbus or light-ring. This, as will be seen on examination, differs in appearance from the streaks emanating from Tycho, Copernicus, Kepler, and Aristarchus. Kepler (144), by the way, may be here referred to as a crater, close upon 22 miles across, the centre of a great system of light-streaks, uniting with those from Copernicus. Close to Euclid lie the Riphæan Mountains (220). Under oblique illumination they strongly suggest an exaggerated, or caricatured, bas-relief of a llama or giraffe. One of the deepest craters in the Sea of Clouds is Bullialdus (213), to which a light-streak extends (as mentioned on page 35) from Tycho (180). This is $38\frac{1}{2}$ miles across, with finely terraced walls of considerable breadth, and a fine central mountain 3,000 feet high. The considerable crater or ring-plain, breaking into the southern wall, too, will at once strike the eye, while a very similar one (but detached from Bullialdus proper) will be noted to the south of this again. Campanus (226), a ring $30\frac{1}{2}$ miles across, in this neighbourhood, is chiefly remarkable for the darkness of its interior. Hainzel (237) is a kind of pear-shaped ring-plain, 55 miles in its longest diameter, with high and precipitous walls rising some 11,600 ft. in places. The wall of Capuanus (238), too, will repay examination under suitable illumination. Capuanus is one of the comparatively few craters that remain conspicuous and identifiable when the moon is full. We are now in the neighbourhood of the Sea of Moisture (T in our map). The student may begin his examination of this region with the large bay in this 'sea,' Hippalus (225). The chief interest, however, attaching to this locality resides in the wonderful

system of 'rills,' or narrow and tortuous clefts, existing to the west of Hippalus. The majority of these require a large instrument for their detection, but one or two of them are within the reach of a three-inch telescope when the moon is between nine and ten days old. The formation of Vitello (229) seems to afford an illustration of the vulgar phrase, 'a wheel within a wheel,' inasmuch as the outer ring-plain encloses another one, from the interior of which rises a mountain, 1,600 ft. or 1,700 ft. high. With the examination of Gassendi (232), on the northern boundary of the Sea of Moisture, we shall conclude another night's work.

Our sketch of this fine and interesting formation was made with a power of 160, the moon being 11·24 days old, and Gassendi very nearly on the terminator. The diameter of this great walled plain is fifty-five miles. The height of its surrounding cliffs varies greatly; in places they rise to an altitude of some 10,000 feet, while towards the south, as will be seen in the drawing I give, they diminish to a twentieth part of that height. It is worthy of remark that Mädler asserts that the floor of Gassendi is in its northern part quite 2,000 feet above the level of the almost adjoining Sea of Moisture. It will be observed how the northern part of the wall has been destroyed by the subsequent eruption in which the great spoon-shaped ring-plain shown was formed. At the epoch of our sketch, the three central mountain masses, rising from the principal plain, were conspicuously shown. It will be seen that the westernmost of these is the largest and highest, the tips of the others only peeping, as it were, out of its shadow. This is a formation which may be advantageously studied continuously during the eleventh and

Fig. 21.—Gassendi.
Moon's Age, 11·24 days.

twelfth days of the moon's age, as it exhibits so many complicated features; and it is most instructive to the beginner to note how these come into view and alter in aspect with advancing sunlight. Moreover, the student should observe it in different states of the moon's libration.[1] The changes produced in the aspect of formations in the neighbourhood of the moon's limb from this cause are most striking and remarkable.

Night Seven.

The light of the rising sun continues to creep over the moon's disc, and we are rapidly approaching her eastern limb; in other words, she is now entering that phase denominated full in the almanacs, when the whole of her surface which is turned towards the earth is simultaneously visible. For reasons before stated, however (p. 16), this is the very worst aspect under which details can be examined, or even identified; and I shall, therefore, describe the leading formations which still remain to be spoken of, as they appear when tolerably near the terminator. And here I may note that ring-plains and mountains situated on, or very near, the actual visible limb of the moon, are seen in a much more natural manner by the terrestrial observer than those more centrally placed on her disc; since they are, of course, looked at much more sideways; like our own mountain ranges as we view them from the surface of the earth. The student will be struck with this if he will go carefully round the eastern (and especially the north-eastern) limb of the moon within a day or two of her being full. It is time, however, that we began our examination of such individual objects as offer points of peculiar interest. Beginning from the south, we shall be struck with the Dörfel Mountains (246 in our map), seen in profile on the actual limb of the moon. The three most conspicuous

[1] For an explanation of lunar libration see *The Moon*, by the editor of *Knowledge* (Longmans & Co.), pp. 118 *et seq.*

peaks of this tremendous range are believed to exceed 26,000 feet in height. The highest mountain in the world, Mount Everest, in the Himalayas, is 29,000 feet in altitude, but did this bear the same proportion to the earth's diameter that the Dörfel Mountains do to the moon's, then would it be 106,079 feet, or more than twenty miles in perpendicular height. In this neighbourhood Phocylides (242) may be looked at as a considerable walled plain, with a flat interior. I, however, mention it here chiefly as a guide to that curious object, Wargentin (243), which looks like an extremely truncated column, some 54 miles in diameter. Webb aptly compares this to 'a large, thin cheese.' When the moon is eleven or twelve days old, Schickard (239), an enormous walled plain, will repay scrutiny. From north to south this measures some 134 miles, and is nearly as broad, though, of course, it is considerably foreshortened as we view it. The interior is very nearly level, but a three-inch telescope will show the diversity of shade which characterises it. Mersenius (231) is a fine ring-plain more than 41 miles across, and contains various small hills, craterlets, &c., quite beyond the power of our instrument. What will strike the young observer is the aspect of its floor, which is convex, like a watch-glass. Just as Fracastorius (372) appears as a bay bounding the southern extremity of the Sea ot Nectar (p. 25), so does Letronne (224), formed by the mountains extending from Gassendi, appear at one extremity of the Sea of Storms (Q). The huge dark plain Grimaldi (272) is nearly 148 miles long by 129 broad, and would have ranked as a 'sea' had it been situated near the centre of the moon, instead of close to her limb. Grimaldi is even darker than Plato, and, as I have previously remarked (p. 22), may often be seen on the dark limb of the moon when illuminated by earthshine. Riccioli (273) is another enormous walled plain, and is very nearly as dark in parts as Grimaldi itself. Just to the south-east of these two last-named formations lie the Lunar Cordilleras (274) and the D'Alembert Mountains (275). What is probably a

portion of this latter chain reappears as the Rook Mountains (276). Rather further south along the limb, when the moon is nearly thirteen days old, the series of ring plains, Lohrmann (153), Hevelius (154), and Cavalerius (155), offers an interesting spectacle. Hevelius has a convex interior, but by no means so regular as that of Mersenius, nor does the convexity fill the enclosed area in the same way. Leaving the moon's limb now for the Ocean of Storms, we arrive at the most brilliant spot on the whole surface, Aristarchus (148), of which I have spoken before (p. 22), as conspicuous on the dark limb when the moon is young. I had a curious illustration of the extreme brightness of this formation on the occasion in which the accompanying drawing was made (the night of August 15, 1883).

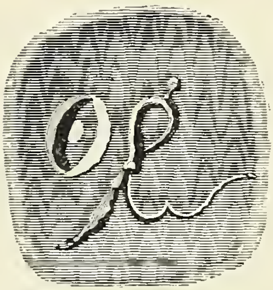

Fig. 22.—Aristarchus and Herodotus. Moon's Age, 12·86 days.[1]

Huge, black, cumulus clouds were driving at intervals across the sky, and several times when the moon was absolutely blotted out from view in the field of the telescope, Aristarchus continued to shine like a small ill-defined planet. It is difficult or impossible to reproduce this extraordinary lustre in a wood-engraving; it is actually unpleasant to the eye even in a three-inch telescope. The diameter of Aristarchus is twenty-eight miles, and its walls are terraced—albeit the terracing is seen with considerable difficulty, owing to the glare. It has a concave interior with a central mountain — if possible even more brilliant than the internal walls themselves. Its eastern wall extends into a table-land by which it is connected with Herodotus (149). This last-

[1] The student is recommended to pass a pale wash of Indian ink over the interior of the crater Herodotus (the right-hand one in the sketch above), as the engraver has mistakenly made it of the same tint as the surrounding Mare.

named formation is less than 24 miles across, and is very notably darker than Aristarchus. The chief object of interest in connection with Herodotus is the curious serpentine valley or cleft which originates in it, and which was well seen when our sketch was made. Schmidt asserts that this is 1,663 feet deep in places. It enters Herodotus at a point concealed by shadow at the epoch of our drawing.

With this will terminate our description of the moon's surface. I have not considered it necessary to make more than casual reference here to the aspect of lunar formations after full moon, inasmuch as it differs only from that which they present before full moon in that, while in the latter case the sun is rising on them and their shadows are cast to the east, after full moon the sun is setting to them and their shadows fall towards the west. Figs. 8, 9, and 10 (p. 25) will sufficiently illustrate this. As I began by saying, I am not writing a treatise on selenography, and my object has merely been to invite the attention of the beginner to certain typical lunar formations, which can be observed with such an instrument as has been employed for the purpose of this work. Our map will in itself supply the student with ample work for a considerable period, inasmuch as it will enable him to identify four hundred of the principal formations on the face of the moon. The possessor of a telescope whom I may have succeeded in interesting in the study of lunar detail will probably procure Neison's great book on 'The Moon,' a work containing more detailed information with reference to selenography proper than any one extant in the English language.

CHAPTER IV.

OCCULTATIONS OF STARS AND PLANETS BY THE MOON.

There are few more curious, instructive, nay, even startling sights in the heavens than the occultation of a fixed star (or more rarely of a planet) by the moon. When this occurs at the dark limb of our satellite, its suddenness is such as not infrequently to extort an exclamation from, as it invariably causes a start by, the observer who witnesses it for the first time. The moon, as everybody knows, completes a sidereal revolution round the earth in about 27·32 days; in other words, that period elapses from the time of her quitting any given star to her return to it again. It may be worth while to mention incidentally that while the moon has thus been travelling in an easterly direction through the sky, the sun has also (apparently) been moving, much more slowly, in the same direction; so that if we assume that the sun and moon are in conjunction (the 'new moon' of the almanacs), at the end of the 27·32 days the moon will not have overtaken him; in fact, she will have to go on for 2·21 days before she comes up with him, and it is new moon again. It is this period of 29·53 days which forms the lunar or synodical (Greek, Σύνοδος, a meeting) month of the books on astronomy. In thus describing her monthly path over the celestial vault, it is quite obvious that she must pass between us and such stars as lie in her course; the stars being—for our present purpose—at an infinite distance, while she is only some 239,000 miles from us. Her orbit is, however, very far indeed from being a fixed

circle in the sky. Its mean inclination to the ecliptic is about 5° 9′; but its nodes (the points where it cuts the ecliptic or plane of the earth's orbit) are perpetually shifting. The moon's perigee, or nearest point to the earth, is shifting; and, in fact, to put it shortly, at the end of any month the moon does not return accurately to that point of the sky from which she set out. Were the path of the moon a definite and unalterable one in the heavens, she would, of course, occult the same stars over and over again, month after month. As a matter of fact, she only does this, and that but approximately, after 223 lunations—a period known to the Chaldæans of old as the Saros. Very well, then, travelling thus, as I have said, from west to east, her eastern limb is, of course, the leading one, or that which covers, hides, or occults the objects lying in her path. From new moon to full moon this limb is unilluminated, and the effect of the extremely sudden extinction of a star when the dark limb hides it is, as I began by saying, of an absolutely startling character. 'In a moment, in the twinkling of an eye,' the star which shone as a brilliant point in the sky is blotted out; and its place seemingly knows it no more, until it reappears from behind the opposite or illuminated edge of the moon. After full moon, of course, the eastern limb is illuminated, so that the disappearance takes place at the bright edge, and the star on its reappearance starts instantaneously from behind the dark limb. A few days on either side of new moon, when the dark limb is visible by earthshine—or, in the popular form of expression, we can see the old moon in the new moon's arms—a new charm is added to the spectacle of an occultation, inasmuch as before full moon the faintly lighted dark limb can be actually seen approaching the star which it is soon to obliterate. Now it fortunately happens that occultations are phenomena peculiarly within the range and capability of a three-inch telescope. Moreover, should the owner of such an instrument happen to possess a trustworthy chronometer or regulator, he may not only derive great personal

pleasure and amusement from the observation of the phenomena of which I am treating, but may render real and enduring service to science by the publication of his observations of the occultations which are predicted in the 'Nautical Almanac.' It may encourage the student and young observer to be assured that observations of occultations made with a three-inch telescope and an accurate chronometer, may be of real service in correcting the lunar tables, and the theory generally. As an illustration of the preceding remarks, I will take the occultation of λ Geminorum by the moon, which happened on Thursday, March 6, 1884. Our sketch represents the aspect of affairs at 10h. 10m. 4s. p.m., at the instant of the star's disappearance at the moon's dark limb, as seen in a three-inch telescope armed with a Huyghenian (inverting) eyepiece magnifying 80 diameters.

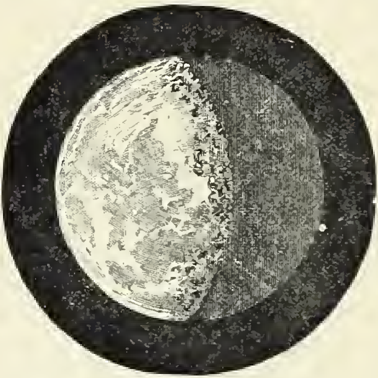

Fig. 23.—Occultation of λ Geminorum by the Moon, March 6, 1884, power 80.

The reappearance happened at a point in the bright limb which may be found in the engraving by opening the legs of a pair of compasses 0·55 in., and placing one leg on the lowest illuminated point of the moon's disc; then will the other leg cut the bright limb at the spot at which it took place. It occurred about 11h. 12m. 9s. p.m. Let us now turn to p. 435 of the 'Nautical Almanac' for that year, and see in what form this phenomenon is there predicted, with a view to explaining and utilising such prediction for the information and instruction of the student.

OCCULTATIONS VISIBLE AT GREENWICH.

Month and Day	Star's Name	Magnitude	Disappearance				Reappearance			
			Sidereal Time	Mean Time	Angle from		Sidereal Time	Mean Time	Angle from	
					N. Point	Vertex			N. Point	Vertex
			h. m.	h. m.	°	°	h. m.	h. m.	°	°
Mar. 6	λ Geminorum	$3\frac{1}{2}$	9 10	10 10	107	134	10 11	11 11	226	262

⁎ The angles are reckoned towards the right hand round the circumference of the moon's image, as seen in an inverting telescope.

The first column gives the date; the second, the star's name; the third, its magnitude; the fourth, the sidereal time—or that shown by an ordinary observatory clock—at which the disappearance takes place; and the fifth, the corresponding instant of mean solar time at which the star vanishes. The sixth and seventh columns require more detailed explanation. The 'north point' of the table is that point of the moon's limb cut by a circle passing through the north pole and the moon's centre. It is in real truth the *south* point of the lunar limb; but it is uppermost in the field of view, and is known technically as the N. point. From this, angles are measured right round the moon's circumference, in the direction in which the hands of a watch move. Our second figure will illustrate this. This will render the mode of measurement intelligible at a glance. Here, evidently, 0° is the moon's (technical) N. point, and the measurement of angles from it is indicated by the figures. Suppose, for example, that we found from the tables that the angle from N. point of some star at

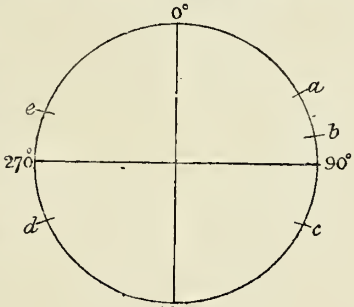

Fig. 24.

disappearance was 60° ; then should we know that it would be occulted at the point marked *a* in our diagram. Were the angle 79°, it would disappear at *b*, 116° at *c*, and so on. Were, on the other hand, the angle of reappearance given as 245° from N. point, *d* would be the point in the limb from which it would emerge, as would *e* were such angle 292°. These 'angles from north point' are employed with telescopes mounted equatorially (Chap I. p. 5). When the observer has only an altazimuth mounting (*loc. cit.*), as is usually the case with a three-inch telescope, the angles must be measured from the moon's vertex. This, in effect, is the point in her limb at the top (in an inverting telescope) cut by a plumb-line passing through her centre. I have so far spoken as though the disappearance of stars was in all cases instantaneous, and so, as far as my own experience goes, it is. Other observers, though, have seen the very curious phenomenon of the apparent projection of the star on to the (almost invariably bright) limb of the moon. It is a noteworthy fact that this curious appearance has been practically confined to red stars, like Aldebaran ; but this goes a very little way in helping towards a solution of so anomalous an effect. The occultations of planets are comparatively rare phenomena, and should be sedulously watched whenever they occur. An occultation of Venus occurred about three o'clock in the afternoon on February 29, 1884 ; but no intimation or prediction of it whatever was given in the 'Nautical Almanac' ! Occultations of Saturn and Jupiter afford delightful spectacles to the observer ; the extreme sharpness of their superficial detail, where actually in contact with the moon's limb, entirely negativing any suspicion of a lunar atmosphere. Irrespectively altogether, however, of the mere beauty and interest of the phenomena of lunar occultations, and their entire suitability for observation with our instrumental means, I would, in conclusion, once more insist on their scientific value. Made simultaneously at stations, the longitude of one of which is

well determined, they afford excellent (if somewhat operose) means of deducing that of the other. Moreover, as I have before said, if the student be the possessor of a chronometer indicating accurate Greenwich mean time, he may by his own unaided exertions render real help towards the improvement of the lunar theory, and perchance earn a niche in the Temple of Fame in days yet to come.

CHAPTER V.

MERCURY.

MERCURY in a three-inch telescope is, to speak as euphemistically as possible, a rather disappointing object. Nor is the reason far to seek. Even in inferior conjunction—when (save during the rare occasions of his transit over the sun's disc) he is, of course, invisible—his diameter scarcely exceeds 10″; while at the times of his greatest elongation—east or west of the sun, as the case may be—his little crescent only measures some 7″ from cusp to cusp. Hence it becomes necessary to employ as high a power as our telescope will bear to get any idea of the planet's figure and general appearance; while as to the detail alleged in astronomical works to have been seen on his surface, the possessor of such an instrument as that with which our observations are made must be content to walk by faith, and not by sight. The explanation, which will be found in the next chapter, of the phases exhibited by Venus is equally applicable, *mutatis mutandis*, to those shown by Mercury, and the reader is requested to turn to what is said in the place cited, for the better apprehension of what is to follow. Mercury then attained his greatest elongation west of the sun at 7 p.m. on September 18, 1885, and hence, at the date of our observation, he was about three days and a half from it. A glance at the figure will show that the illuminated portion of the planet visible was decidedly *smaller* than it should theoretically have been from the relative positions

of the Sun, Earth, and Mercury. As may be imagined, however, some attention is needed to detect this feature in so tiny a crescent as the planet presents. The shading towards the terminator, or apparent inner edge of the crescent, is both considerable and ill-defined. Whether this has its origin in the planet's atmosphere or not is by no means easy to determine. The student, after scrutinising Mercury, should turn his telescope upon Venus (should she be conveniently placed), the brilliance of whose light stands out in striking contrast to the comparatively feeble illumination of her inner neighbour. Spots, streaks, &c. (whence a hypothetical rotation period has been deduced), and a blunting of at least one of the horns of the crescentic planet have been seen, either objectively or in imagination, by many observers ; but, as I have hinted above, all such detail is hopelessly beyond the possessor of a small instrument.

Fig. 25.—Mercury, Sept. 15, 1885. Power, 160.

As in the case of Venus, when Mercury is in or near either of his nodes at the time of inferior conjunction, he passes across the sun's disc—or, as it is technically said, 'transits' the sun as a black spot. With too light an eye-shade he shows well the notorious ligament or black drop (concerning which so much has been written in connection with transits of Venus) at his entry on and exit from the sun's face. An aureola or luminous ring round the black disc of the planet has also been seen while it has been crossing the sun ; while several observers of skill and repute have seen one, and even two, whitish spots on the dark disc of the planet itself under the same conditions. These phenomena are quite within the reach of such a

telescope as that whose use I am presupposing; but, unfortunately, the student will have to wait some time before attempting to verify such observations as those which I have just described, inasmuch as only two more transits of Mercury will occur during the present century: the first happening on May 9, 1891, and the next on November 10. 1894.

CHAPTER VI.

VENUS.

THE glorious planet we are now going to examine surpasses, under certain circumstances, every object in the sky in lustre; and hence the poet, in saying that—

> Hesperus that led
> The starry host rode brightest,

simply expressed a bald matter of scientific fact. About a month after she has attained what is called her greatest elongation east, or the same time before she acquires her greatest western elongation, she may be detected with the naked eye in the sunlit sky; and, when in the former phase, casts a very perceptible shadow at night upon any white surface. Her great brilliance under these conditions renders her the most severe test of the achromatism of a telescope that we possess; and an instrument must be perfect indeed that will exhibit an absolutely colourless image of her at this time.

In order that the beginner may have an intelligent idea of what he is going to look at, it will be necessary to recall a few elementary facts in connection with the orbits of the Earth and Venus. Everybody—at least, everybody who will read these lines—knows that Venus goes round the sun in an orbit inside our own; in other words, her mean distance from our mighty centre of light and heat is $66\frac{3}{4}$ millions of miles, while ours is $92\frac{1}{3}$ millions. She travels through this orbit in 224·7 days. Now, if we were standing still,

she would go through all her phases in this period ; and if she were in, say, inferior conjunction (i.e., in a line between the Earth and the sun) on any given day, after 224·7 days she would return to the same spot. But the Earth itself goes round the sun in 365·26 days, of course in the same direction as Venus, so that what is called her synodic period (Greek, *σύνοδος*, a meeting), or time elapsing between one meeting with the Earth and the next, is really 583·92 days. For example, Venus was in inferior conjunction with the sun at 2 a.m. on July 12, 1884. Her next inferior conjunction did not happen until 7 p.m. on February 18, 1886. Now, if we suppose her to be in inferior conjunction, and also in or near one of the nodes of her orbit, it is pretty evident that she will pass across the face of the sun as viewed from the Earth, and we shall have a transit of Venus. With this phenomenon, however, we have but small concern here. It last happened on December 6, 1882, and will not recur until June 7, 2004, when the hand that pens these words and the eyes which rest upon them will alike be dust and ashes. If, though, the planet is far from her node at the time of inferior conjunction, then she passes above or below the sun as seen by us. On July 12, 1884, she was nearly 5° south of the sun's centre. Under these circumstances, as we shall presently see, while nearly the whole of her lighted face must be turned towards the sun, yet an extremely narrow portion of her illuminated limb is perceptible. As she travels to the westward of the sun after this as a morning star, more and more of the lighted part of her disc becomes visible ; until she assumes the appearance of the moon when in her first quarter; or, technically speaking, is 'dichotomised.' As will be seen by any one who will draw a diagram or plan of Venus's orbit, her diameter must appear the largest at the time of her inferior conjunction, and must diminish just as her illuminated surface increases. After attaining her greatest elongation west of the sun (which can never exceed 47° 15′), the planet appears to begin to move back again, or from west to east, grows

smaller and smaller, and when her disc is becoming fully illuminated, disappears behind the sun in the glare of his light, as merely a rather big star. She is then said to be in superior conjunction. Emerging, after an interval, from his rays to the east of him, she becomes an evening star, and goes through all her phases in the reverse order, increasing in diameter as the area of her illuminated surface diminishes. Attaining her greatest eastern elongation, and then turning back as a rapidly narrowing crescent, she finally returns to inferior conjunction again. This all being understood, we will, at last, go to the telescope.

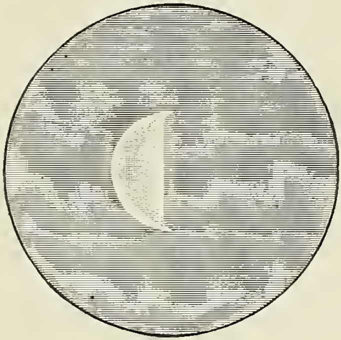

Fig. 26.—Venus, May 10, 1884. Power, 160.

At 6 p.m., on May 2, Venus had attained her greatest elongation (45° 27′) east, and eight days later the accompanying drawing was made, with a power of 160, in a 3-in. telescope. Now two or three things will strike the observer who will carefully scrutinise this sketch. Perhaps the first will be the great brilliance of the illuminated limb of the planet, and the way in which this contrasts with the inner portion or 'terminator,' shading off into the bright sky. This is very imperfectly shown in the engraving, where the inner edge is represented much too bright. The two little cusps, too, so sharp and bright, will certainly catch the eye, from the want of correspondence of their inner edges with the interior curve of the planet's lighted surface. All this seems indicative of a dense and extensive atmosphere surrounding Venus. One effect of the inner shading is worthy of note, and that is the effect it has in reducing the area of the planet which should be theoretically illuminated. If we draw a plan of the orbit of Venus, we shall see that at her greatest elongation she ought geometrically to be dichotomised, i.e., exactly

half full; but it will be seen that in reality she is rather less than this, the degradation of light towards the terminator being pretty rapid. Observers of repute have seen the terminator jagged and uneven, like that of the moon; but it is too much to expect of a three-inch telescope that it should exhibit such difficult features as this. A blunting of one or both of the horns has also been perceived at times by various astronomers, both in this country and on the Continent. And, what is of considerable interest to the possessors of instruments of the size employed for the purpose of these descriptions, very faint dusky spots and bright patches have been perceived from time to time in telescopes of the most varying apertures; small ones showing these spots as well as —in fact, better than—some of the larger instruments. This may possibly arise from the general glare of light in a large objective or mirror deadening the eye to such delicate details. It is by the aid of these spots, real or imaginary, that the hypothetical period of rotation of Venus has been determined.

But, however beautiful and curious the spectacle may be which is presented by Venus in quadrature, it will scarcely interest the student so much as his first view of her in inferior conjunction. Our succeeding figure exhibits the planet as seen in the same instrument and with the same power as that employed to make our first sketch with. The contrast between these two aspects of Venus will arrest the attention at once. The comparatively small half-moon has become converted into a hair-like glittering semicircle of light, enclosing something which is certainly darker than the surrounding sky. The very abnormally hazy condition of the atmosphere which had persisted for many months was against the perception of any very delicate gradations of shade, so that the whole of the dark body of Venus was invisible; but the effect, difficult or impossible to reproduce in a wood-cut, was that of a disc, dark where embraced by the crescent of light, and fading into the light of the sky outside or beyond the cusps. On the occasion of former

inferior conjunctions, the whole of the planet's dark limb has been unmistakably perceived. In order that it may be seen to the greatest advantage, a *very* small diaphragm should take the place of the ordinary one between the two lenses of the Huyghenian eye-piece. A blackened card disc with a fine hole made centrally in it with a red-hot needle answers capitally. The hot needle burns the fringed edge of the perforation and leaves it clean and sharp. The smaller the hole, consistently with distinct vision, and the more sky light that is cut off, the sharper and better will

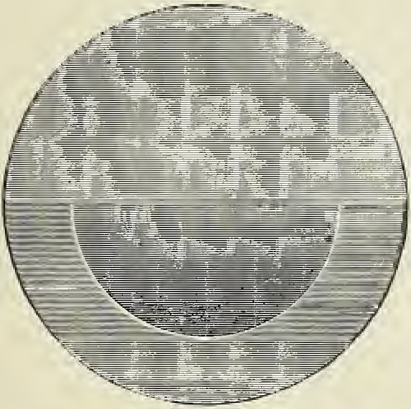

Fig. 27.—Venus in Inferior Conjunction, July 11, 1884. Power, 160.

the body of the planet appear. This little device will always be found useful when any body is to be viewed in bright sunlight.

There is a queer story—or, perhaps, it would be more correct to say a series of queer stories—with reference to various observations of a satellite or companion to Venus, situated always close to the planet, sometimes on one side of her, sometimes on the other, but always exhibiting a phase identical with hers. The most feasible explanation of this is that it has had its origin in each case in what is called

'a ghost' in the eye-piece, i.e. in a reflection of the planet's image from the convex surface of the eye-lens on to the plane surface of the field-lens, and so back to the eye of the observer. An observation made by Short, the famous optician, in 1740, who did use two different telescopes, seems the only one to throw any legitimate doubt upon this explanation. M. Houzeau, the eminent Belgian astronomer, however, is so convinced of the objective reality of the various apparitions of this satellite, that in *Ciel et Terre* for May 15, 1884, he gravely propounds the hypothesis that a little planet (which he provisionally names Neith) revolves round the sun in an orbit just exterior to that of Venus herself. Here there is an opportunity for the student to distinguish himself. He has only to watch Venus day and night, until he picks up this attendant, to do so. Whether, though, he succeeds or whether he fails in this attempt, he will find himself amply repaid for any amount of labour by the diversified but always beautiful appearance of the planet as she speeds on her path round the sun, and may find infinitely less profitable ways of spending his time than by the devotion of a daily half-hour to watching Venus in a three-inch telescope.

CHAPTER VII.

MARS.

The study of Areography (Greek Ἄρης, Mars), or minute Martial detail, can only be properly carried on by the aid of a telescope of considerable size and power. Notwithstanding this, we shall find that a good deal that is curious and instructive in connection with the physical structure of this planet is well within the capabilities of the instrument we are using; and I propose in this chapter to examine such features of his surface as are susceptible of exhibition with only three inches of aperture. A haze of cirro-strati is drifting over the sky as I turn my telescope on to Mars; but this really has the effect of subduing the general glare of the planet, sharpening such detail as is perceptible, and improving definition generally. Compared with the mighty orb of Jupiter, Mars presents such a small disc that we find it necessary rather to overpress magnifying power than otherwise, to see fairly the principal markings he exhibits. We arm then our instrument with a power of 204, and, on directing it to the planet, behold the spectacle depicted in the above engraving.

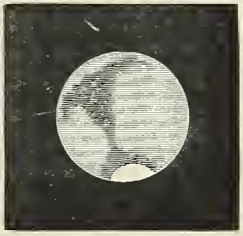

Fig. 28.—Mars, Feb. 18, 1884, 9h. 35m. G.M.T. Power, 204.

Unlike Jupiter and Saturn, the disc of Mars—in its present phase—appears circular. When Mars is in so-called

'quadrature' with the sun, he will be very perceptibly gibbous (fig. 36, p. 81), but under no circumstances has any trustworthy measurement shown a sensible excess of his equatorial over his polar diameter. Dawes found the ellipticity absolutely imperceptible. Regarding then this circular disc, what do we see? A bright white patch at the bottom—or north pole—of the planet is probably the first thing that will arrest the attention of the observer, contrasting as it does markedly with the general orange tint of the planet. Bounded on one side by the limb, this brilliant marking exhibits the form of a double convex lens. It is entirely surrounded on its southern, or upper edge, by a greenish-grey dark marking, from which rises another of a shape akin to that of the old-fashioned champagne-glass of the days of our fathers and grandfathers. Instead, however, of terminating in a symmetrical rim, the southern extremity of this bifurcates in a fashion which somewhat suggests the spreading of the wings of a sea-gull. The central southern portion of this is the darkest part of it. Our sketch was made, as stated above, at 9h. 35m. at night. Had I deferred it until four o'clock the next morning, the planet would have presented a very different aspect indeed; for Mars rotates on his axis in 24h. 37m. 22·735s. (thus taking a little more than half an hour longer than the Earth to complete one rotation), and from this cause, of course, fresh portions of his surface are presented to our view as the night advances, just as in the case of Jupiter. There is, however, this very notable difference between the markings on the two planets, that whereas, as stated on p. 67, the detail on Jupiter is in no legitimate sense permanent, existing as it probably does in a vaporous and very mobile envelope of enormous extent, in Mars the markings are persistent, and certainly form parts of his actual solid (and liquid) surface; so that maps of no inconsiderable accuracy have been formed of them. What, then, do they signify? It seems in a high degree probable that, in looking at Mars, we are regarding a miniature of our own world. That the

general surface of the planet may well represent land of a geological structure allied to the 'Triassic,' or New Red Sandstone rocks so well displayed at Exmouth, Dawlish, and Teignmouth in this country; that the darker markings are nothing but oceans, seas, straits, and lakes; while the conspicuous white patch at the pole has its origin in the existence there of the huge tracts of glacier and snow-covered land and ice-locked sea of the Martial arctic regions. For, during the present opposition of Mars, the north pole of the planet is turned towards the earth, and it will be seen, from the position of the planet's axis with reference to us, that his south pole is wholly hidden, from being on the other side of him. The reason for this is worthy of a brief examination. Mars goes round the sun in 686·98 days, the Earth describing her orbit in 365·26 days; so that, being in opposition at any given date, an interval of 779·84 days must elapse ere they return to it. At least, this is the mean period between two successive oppositions; but, owing to the great eccentricity of Mars' orbit, this varies as oppositions occur near his perihelion or aphelion (points of his nearest approach to and greatest recession from the sun) respectively. Moreover, the equator of Mars is inclined some 27° to the plane of his orbit. As the inclination of our own equator is only $23\frac{1}{2}$° to the ecliptic, it is evident that the vicissitudes of the Martial seasons must be more aggravated than in our own case. But we have spoken of this tilt of the planet's axis mainly for the purpose of pointing out that while at certain oppositions the north pole of the planet must be turned towards us, at others we must see his south pole; while at intermediate points—answering to our terrestrial equinoxes—we must see both poles, just as in the circular maps of the earth which form the frontispieces to so many books on geography. The south pole of the planet, as I have said above, is wholly invisible now; but, during the memorable opposition of 1877, a great white lenticular-shaped patch on the southern limb of Mars formed just as conspicuous a feature as the corresponding north polar one

(then invisible) does now. From all this it will be evident that to get a true idea of Areographical detail, we must watch, and carefully draw, Mars during several oppositions. It is very remarkable to note what a curious change in the aspect of any given feature, far north or south of the equator of Mars, is produced by foreshortening. Nothing but long-continued observation and abiding faith in the irrefragable principles of perspective will enable the student to identify a given spot or marking when viewed under so very different an aspect. The best popular map extant of the leading Martial details is the one given by Prebendary Webb on p. 146 of his altogether admirable book, 'Celestial Objects for Common Telescopes.' It is, however, drawn on Mercator's projection, with its grossly exaggerated polar dimensions; and the young observer must make allowance for this in using it for regions removed by any considerable distance from the equator. The great inverted conical marking shown in our sketch (p. 59) is chiefly composed of the Kaiser Sea. The thin arm stretching out to the left is a part of Flammarion Sea; that to the right a portion of the Dawes Ocean. The Delambre Sea (confused by foreshortening with Nasmyth Inlet to the right) forms the dark marking surrounding the snow-cap at the north pole (bottom) of the planet. Situated some 150° in longitude from the Kaiser Sea is a very notable marking in the southern hemisphere of Mars—unfortunately in an unfavourable position for the observer just now—which is called Terby Sea, and which, surrounded by Kepler Land, presents a somewhat ludicrous resemblance to an eye. In the absence, however, of a map, detailed descriptions of particular markings become merely nugatory.

It only remains in conclusion to mention a few facts in connection with the general aspect of the planet. I have spoken of the very conspicuous white patches at or near the poles of Mars—patches occasionally so brilliant that irradiation causes them to appear as positively projecting slightly

beyond the outline of his limb. That these, as I have previously intimated, consist of ice or snow, or both, the evidence afforded by the spectroscope seems to render practically certain, showing as it does the presence of large quantities of aqueous vapour in the Martial atmosphere. There is, however, a somewhat similar appearance, which I have, among others, myself observed, that of lenticular-shaped white markings round the limb, which are by no means so easily explicable. A very little attention will show the observer with the telescope that the ruddy tint of the planet's face is most marked towards the centre of the disc, and that the limb is notably paler (occasionally so much so as to seem nearly white, as was the case in the autumn of 1879); but the markings of which I am now speaking are large white patches in the eastern and western limbs of Mars, for which it is anything but easy to account, though they are probably atmospheric. An extremely ingenious explanation of the general brightness of the limb will be found on page 65 of the 'Essays on Astronomy,' by Mr. R. A. Proctor. Mars has been described as a miniature of our own earth; and undoubtedly he does present features connecting his physical structure more closely with ours than any other planet; but still, irrespectively of size, there are differences which cannot fail to strike the thoughtful observer. The most salient of these is the difference of distribution of land and water. On the earth only about 51,500,000 square miles consist of dry land, while 145,500,000 square miles are covered by water. On Mars the land so far preponderates that the largest oceans, or rather seas, can only be described as more or less landlocked. Schiaparelli claims to have discovered a strange network of 'canals,' uniting various portions of the seas of the planet hitherto considered to be isolated; but, admitting for argument's sake the objective reality of these features, they are hopelessly beyond the optical power we are employing. I may mention, in conclusion, that a curious

collateral indication of the existence of clouds, or vapour in some form, has been observed in the shape of the dimming or partial obscuration of spots and markings on the surface of Mars; while others, at no great distance, have simultaneously retained all their usual sharpness and comparative precision of outline.

CHAPTER VIII.

JUPITER.

There is assuredly no member of the planetary system which offers so diversified a series of phenomena to the contemplation of the student as the noble one which I propose to examine to-night. Exceeding the earth in volume between thirteen and fourteen hundred times, and reflecting (as has been calculated) some sixty-three out of every hundred parts of the sun's light that falls upon him, Jupiter exhibits a disc and shines with a lustre which renders him a conspicuous object in the smallest telescope. Now it might be supposed, from the brightness of the planet, that a high magnifying power would be most applicable to his examination; as a matter of fact and practice, however, it is found that he will not bear so much amplification with advantage as his much dulier neighbour Saturn. Moreover, all the curious detail of which I am immediately about to speak is much better seen when a slight haze overspreads the sky and softens the glare of light on Jupiter's disc, which, in itself, forms an impediment to the perception of very delicate markings. Happily for us, such a haze does cover part of the sky on the night which I select for our drawing. Wishing to use as much magnifying power as I can without impairing definition, I, as a limit, fix on 50 to each inch of aperture of our telescope. Arming it, then, with a power of 150, I turn it on to the planet, to behold the spectacle of which the engraving (p. 66) gives a pretty accurate idea.

The first thing that will probably arrest the attention of the young observer is the shape of the planet. Instead of presenting a circular disc it will be seen to be very notably elliptical; in other words, flattened at the poles, and bulging out at the equator. And next, as the eye gets accustomed to the image, a series of belts of different depths of shading and even of markedly different colours will be seen, striping Jupiter's face in a direction parallel to his equator. Let us

Fig. 29.—Jupiter. Jan. 24, 1884, 9h. 5m. p.m. Power, 150.

take those visible when our drawing was made. I will begin at the top of the planet, which, as all astronomical telescopes invert, is, of course, its south pole. For some little distance the tint is pretty uniform—or as an artist would say, 'flat;' but then it is seen to consist of a series of stripings; the lighter divisions between them being well marked and easily visible as we approach the northern edge of this polar capping. Then comes a distinct white streak, bounded on the north by the principal belt in Jupiter's disc. This is the

most conspicuous feature on the whole face of the planet. It is of a decidedly brownish tint, and its northern edge shows a marked tendency to throw out small projections, so as to give a kind of 'scalloped' effect. With a larger instrument the dark matter of this belt is seen to emit prolongations or streamers of a wispy character from these projections diagonally across the broad bright equatorial interval; but what I have drawn (p. 66) shows everything that it is within the power of a three-inch telescope to reveal. The northern and fainter of the two equatorial dark belts is in its turn succeeded by yet another white streak; that by a fainter dark one still, while a multiplicity of stripes covers the north pole of the planet with a shading which, like the south polar capping, looks practically 'flat' or homogeneous. A little attention will show that the east and west 'limbs' (or edges) of the disc are not quite so bright as its central parts, and that a slight fading away of the belts is perceptible as they approach the limb. The satellite and its shadow visible on the left-hand western (or 'preceding') limb of the planet will be dealt with by-and-by. It must not, however, be supposed that the markings I have described are constant or permanent, like the oceans, seas, continents, and islands of our own earth; or that a map of Jupiter constructed from observations now would be of much use in, say, 1889. Moreover, confining ourselves to a single night's observation, the details on the surface of the planet will be seen to undergo a very marked change in the course of four or five hours' persistent watching of them; for the simple reason that Jupiter is rotating on his axis at a speed so tremendous as to be beyond our power of realisation. The notable markings which appear from time to time upon his face give obvious indications of proper motions or driftings of their own, and this complicates and renders uncertain the exact determination of the period of the planet's rotation. It would, however, seem that he turns on his axis in a period not differing greatly from 9h. 56m., so that a spot on his equator must travel

at the rate of over seven miles a second! A simple plumb-line must form an effective transit instrument in such a favoured locality! Well, then, by his mere rotation fresh features are brought into view; but after the lapse of nine or ten hours we shall revert to that aspect of the planet which it presented when we commenced our watch. These changes, therefore, are simply such as arise from viewing in succession the markings extending over the whole of Jupiter's spheroidal surface—of which, of course, only one half is visible at any one given instant. I have now to speak of the much more remarkable changes which occur in the markings themselves in the course of months or years. As a familiar example, I may refer to the wonderful great, oval, red spot which appeared on the face of the planet to the south of the southern one of his equatorial belts in the year 1879, and which persisted in a perfectly visible form up to 1883; although it has now entirely vanished in a three-inch telescope. In August, 1878, a great circular white spot formed a most conspicuous object on the planet's equator, and in the succeeding year one enormous dark belt, covering Jupiter's equatorial regions, was broken up, or perforated, as it were, with similar but more irregularly shaped white markings. In 1880, a sinuous continuous white marking separated the equatorial belt into two—the red spot at this time appearing of a pale scarlet tint. In 1881, the red spot persisting, the belts became much narrower, and the 'van-dyking' or 'scalloping' of the northern edge of a dark one south of the equator was even more marked than the similar phenomenon in the somewhat corresponding dark streak shown in our sketch above. And so I might go on detailing a series of most curious changes which have occurred during the last five-and-twenty years, but for the fact that my object is the practical one of teaching the student exactly what to look for, rather than merely the giving a list of other people's observations. With one concluding remark, then, on the phenomena of Jupiter's disc proper, I will pass to the consideration of those of his satellites. It is

this. Jupiter is much too far off to exhibit phases ; but he does show an indication of doing so when what is technically called in quadrature, or when he is 90° east or west of the sun, as measured along the ecliptic. Under these circumstances the limb farthest from the sun exhibits a perceptible shading, much too deep to be confused with the slight fading away of light all round the limb which is always visible.

Beautiful and remarkable as are the unstable details which diversify Jupiter's face, they are, in one sense, almost monotonous as compared with the perpetually changing phenomena of the four moons which circle round him. Of these satellites the first, second, and fourth appear as stars of the seventh magnitude, and the third as a sixth magnitude star. When a satellite crosses Jupiter's face, it is said to 'transit' him ; its entry on to his disc being called its ingress, and the instant of its leaving his opposite limb its egress. When it passes actually behind the planet it is said to be 'occulted ;' and when it plunges into his shadow, to be 'eclipsed.' I am unwilling to introduce anything into this volume not strictly within the scope embraced by its title ; but in order to render what I am about to describe intelligible, it will be necessary to enter into certain elementary explanations of the conditions under which we view Jovian phenomena from our terrestrial standpoint. Leaving, then, our telescope for a few minutes, let S in our figure be the sun, E*b*, E*o*, E*a*, the earth travelling round him in the direction of the curved arrow ; J, Jupiter, also going round the sun in the same direction, but so much more slowly that —for our present purpose—we may regard him as standing still. Then, evidently, Jupiter will cast the conical shadow JUJ′ out behind him into space. Let us call D, R, ST*i*, ST′*e*, the orbit of one of his outer satellites, and conceive it to coincide with the plane of the ecliptic. From E*b* draw the lines E*b*J, E*b*J′ meeting the path of the satellite at I and E′. Now, imagine the earth at E*b*, *i.e.*, before Jupiter comes into opposition (say about the end of November

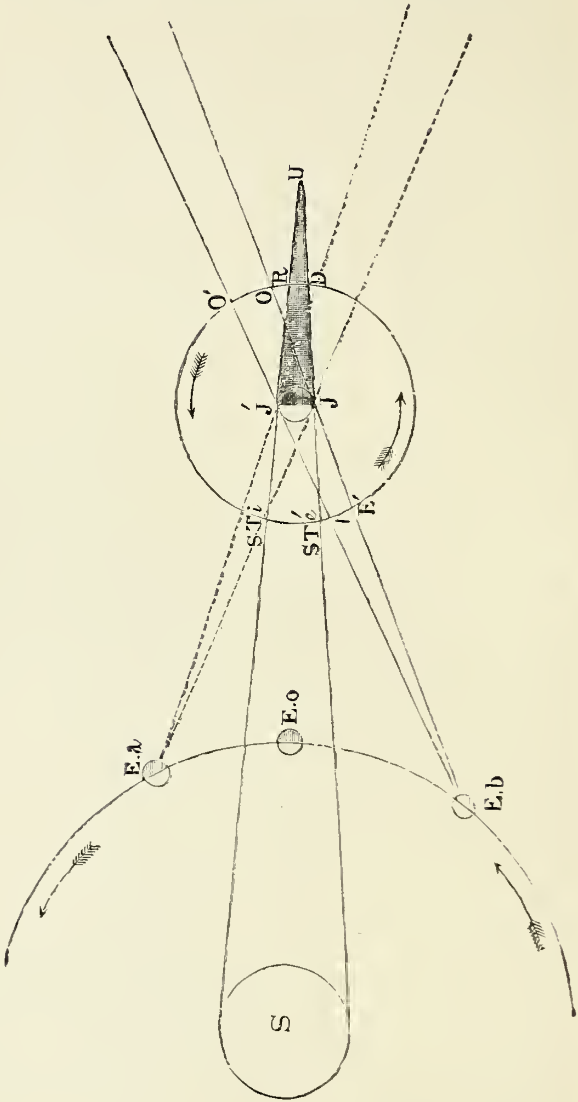

Fig. 30.

1883). Then, when a satellite is at the point I in its orbit on the line E*b*J′, it is seen to enter on to Jupiter's eastern limb, and, when it arrives at E′, to leave his western limb. This, then, is a transit of the satellite. A glance at the figure will show that (independently altogether of the earth's position) when this same satellite passes between the points ST*i* and ST′*e* its shadow must be projected on to Jupiter's face, just as the shadow of our own moon is projected on the earth in an eclipse of the sun, and it is seen to cross the planet as a round black spot. Furthermore, when the satellite plunges into the planet's shadow at D, it disappears in eclipse, to reappear (under the conditions we are supposing) at R. It will, however, be noted that this reappearance from eclipse is only to be followed by occultation behind the body of Jupiter when the satellite reaches O, the satellite finally reappearing at Jupiter's opposite limb when it reaches O′. What I have said, be it remarked, applies only in its entirety to the two outer satellites. The inner ones, which describe smaller circles round the planet, disappear in eclipse, to reappear *from occultation*, as they emerge from the actual shadow behind the body of the planet. It will be further remarked that while the shadow of the satellite enters on to Jupiter's face when the satellite reaches the point ST*i*, the satellite itself does not follow it on to the limb of the planet, to a terrestrial observer, until it arrives at the point I in its orbit. Thus, to sum up, before opposition the shadows precede the satellite casting them in their transits; the inner satellites suffer eclipse and reappear from occultation, and the outer satellites may both disappear and reappear from eclipse on the western side of the planet, to be subsequently occulted by it. When Jupiter is actually in opposition (E*o* in our figure), evidently the satellites will be actually superposed on their shadows as they cross the disc of the planet; and, as the whole of the shadow cone is hidden behind him, occultations only, and no eclipses, can take place. After opposition (a condition of things represented at E*a* above), the sequence of phenomena is

obviously reversed : the satellites precede their shadows over Jupiter's face ; the inner satellites are occulted by the planet and reappear from eclipse ; and the outer satellites may disappear in, and reappear from, occultation to be subsequently eclipsed. The student will now be prepared to understand that when our sketch of Jupiter was made on the night of Jan. 24, 1884, the planet having passed opposition a few days previously, Satellite I., which was about to leave his disc, after crossing it in transit, was slightly in advance of its shadow. In fact, the shadow did not leave

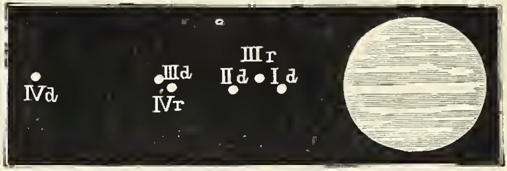

Fig. 31.—Eclipses of Jupiter's Satellites (Dec. 1883).

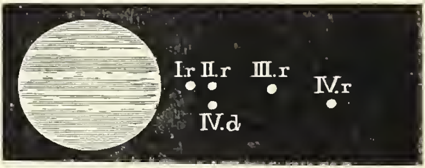

Fig. 32.—Eclipses of Jupiter's Satellites (Feb. 1884).

his limb for seven minutes after the satellite had quitted it. Near quadrature an outer satellite may have left the planet's face for an hour or two before its shadow even enters on to it! The annexed two small diagrams represent, approximately to scale, the points of disappearance in and reappearance from eclipse of the four satellites as seen in an inverting telescope during the months of December 1883 and February 1884. After what I have said, they ought to be perfectly intelligible.

It only remains, in conclusion, to refer to certain curious

phenomena, for which the observer should always be on the alert. In the case of occultations, to begin with, the satellites have been seen apparently projected on the planet's disc; although it seems probable that they were rather seen *through* Jupiter's limb. A star occulted by Jupiter has been seen, in a very large telescope, to fade away in a manner which affords strong confirmation of this idea. When a satellite begins its transit, it may be traced fairly on to the planet as a brilliant spot; but it generally disappears after getting some distance within the limb, its reappearance happening as it is about to pass off on the other side of the planet. I have said that a satellite 'generally' disappears when well within the planet's limb; but very remarkable exceptions indeed to this rule have been witnessed.

I have myself seen Satellite III. quite as dark in appearance as its own shadow when transiting Jupiter, and the same effect has been noticed with IV., and even, more rarely, with II. Again, the shadows, although normally like ink-spots, have been seen of curiously diversified colours. Those of Satellites I. and II. have been noted as grey. I saw the shadow of II. a chocolate-brown in October 1880, and attempted to account for this phenomenon by the supposition that the sun's light must have been shut off from a part of Jupiter's surface glowing with a dull red heat. But as I remarked in connection with the phenomena of the belts, my object here is not to give a mere list of prior observations, but rather to direct the beginner in his own. Under any circumstances I would fain hope that I have said enough to stimulate him to pursue the study of so interesting a system as that of which I am treating, and to impress him with something of the charm and pleasure of the investigation of the leading characteristics of the Jovian system, even in so small an instrument as that whose use I am presupposing.

CHAPTER IX.

SATURN.

Coming as Saturn does into opposition to the sun during the early morning of November 29,[1] with his rings nearly at their greatest opening, and southing in this country at an altitude of between 50° and 60°, the planet could hardly be in a more favourable position for the observer than he is at present. He will be found in the sky just now to the north and west of Aldebaran ('The Stars in their Seasons,' Map I.), and will be instantly identified by the leaden hue of his light as contrasted with the red colour of 'The Bull's Eye.' The subjoined sketch of the planet was made at the telescope with a power of 204 on the night of November 13, at 11h. 45m. p.m.

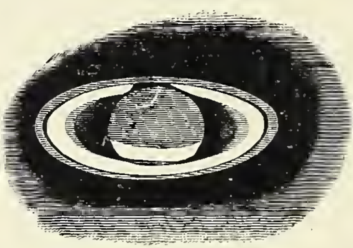

Fig. 33.—Saturn, 1883, Nov. 13, 11h. 45m. G.M.T. Power, 204.

The flattened figure of the planet will at once strike the observer's eye. In other words, he will note that instead of presenting a circular disc, the outline of Saturn is very perceptibly elliptical—or, as it is commonly called, 'oval'—the longest diameter of the ellipse being in the direction of his equator. Technically, his figure would be described as

[1] This was written in 1883.

an oblate spheroid, which, put into plain English, means that instead of the planet being a perfect sphere, he is, as it were, turnip-shaped, *i.e.*, flattened at the poles and bulged out at the equator. This effect of the rapid rotation of Saturn needs no further mention here. The southern part of the globe (that which is uppermost in the telescope) will be seen to be covered by a perceptible dark shading, which, however, terminates with a well-defined edge not far from the planet's equator. Below (north) of this is a bright equatorial band. The general yellow tint of the ball is also a notable feature. Where the ring crosses Saturn's disc a broad line of shading will be observed, and a careful and attentive study of this under good definition will show that it consists of two parts, a dark, broad line of shading crossing, as I have said, the face of the planet ; and seemingly superposed upon it, and in contact with the inner edge of the ring, a very narrow *black* line. This latter is the real shadow of the ring upon the planet. The broader stripe is a part of the strange interior dusky or 'crape' ring, of which I shall speak immediately. If we turn now to the ring itself, we shall perceive that it really consists of two concentric ones, the inner one being very much broader, and notably brighter than the outer one, or than the dusky capping on the southern hemisphere of the planet. A narrow dark line will be seen to separate the inner ring from the outer one. In telescopes of four inches of aperture and upwards this dark division is traceable right round the ring. With a three-inch telescope it will, under favourable circumstances, be well seen in the 'ansæ' (the eastern and western portions of the ring), but will scarcely be fairly discernible entirely round. At moments of the best definition the shadow of Saturn will be seen, as drawn above, projected on the inner ring only, the black line, known from its discoverer as 'Cassini's Division,' at once bounding it and the planet's south pole on the south. The 'crape' ring to which reference has previously been made is just beyond the power of our instrument. On nights when atmospheric conditions

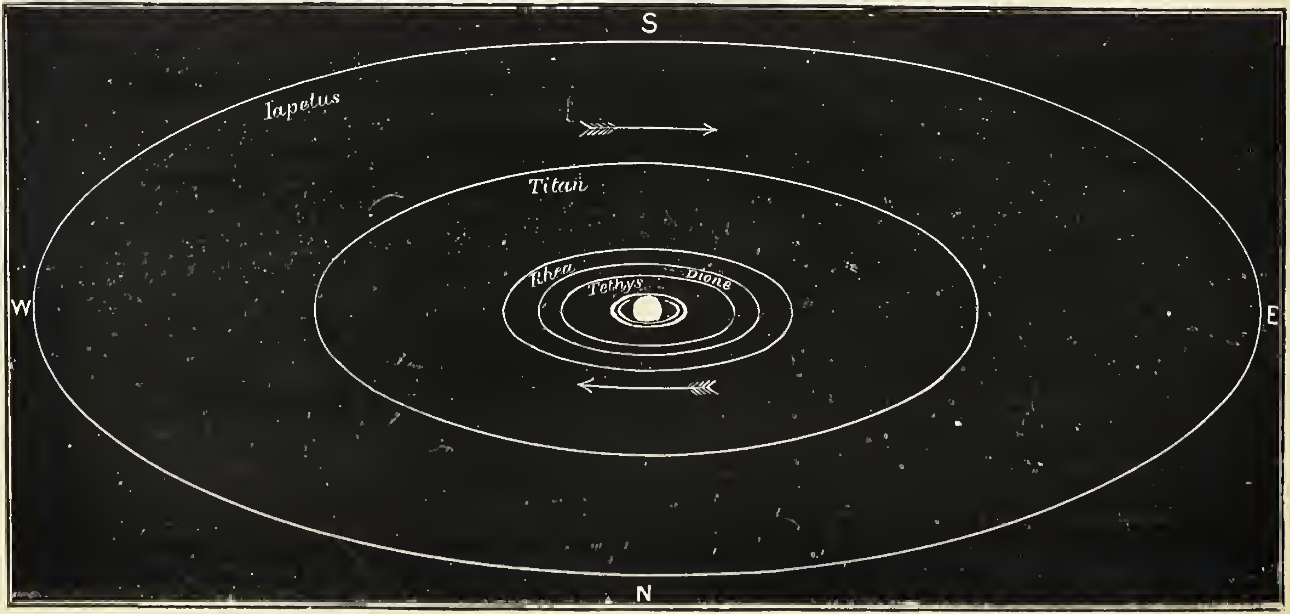

Fig. 34.

admit, however, of the use of a high power, faint indications of it may be seen in the form of a seeming ill-defined shading away of the inner edge of the broad interior ring, in the ansæ. No connection, though, is traceable between this and that portion of the dark ring which is seen crossing Saturn's disc; albeit in larger instruments the whole elliptical outline is seen to be continuous—save, of course, where the planet itself is superposed on it. The rings are known to astronomers as A, B, and C; A being the outer ring, separated from B, the broad bright inner one, by Cassini's division, and C the innermost crape ring which I have just been describing. Ring A itself has been seen to be further cut into two by a division known as Encke's; but assuredly this has never been effected with a three-inch telescope.

Saturn, as may be learned from every primer of astronomy, is attended by eight satellites, of which three are wholly invisible save in large and powerful telescopes. I find that by hiding Saturn behind a very thick wire in the eye-piece, or by any cognate contrivance, the two known as Tethys and Dione may sometimes be glimpsed on a dark night. That named Rhea was even visible in the bright moonlight while the sketch of the planet given on a previous page was being made, and I fancied (although it may have been only fancy) that Tethys sometimes flickered up for a few consecutive seconds at distant intervals. Inasmuch then as, under sufficiently favourable circumstances, the possessor of a first class three-inch telescope may hope to perceive four, or barely possibly even five, out of the eight satellites by which Saturn is attended, I here give a drawing to scale of their orbits, by the aid of which the student may recognise them.

The arrows show the direction of their motion; in connection with which it may be noted that, at first sight, this motion may seem to be *retrograde*. It must, however, be borne in mind that we are looking at Saturn's south pole, and, so to speak, viewing the orbits of his moons from

underneath. In 1899, when the north pole of the planet will be presented to us practically as the south pole is at present, the satellites will be seen to be travelling in the same direction as those of Jupiter, or as our own moon &c. Tethys and Dione must always be difficult objects in a small instrument, and require, as I have said, the planet to be hidden, and a moonless sky, to be even glimpsed in a three-inch telescope. Rhea is a little easier, but will be best seen when at its greatest east or west elongation. Titan, shining as a small eighth magnitude star, is practically always visible. It occasionally transits the disc of Saturn, and under these circumstances its shadow has even been seen as a tiny black dot, crossing the face of the planet, with only $2\frac{7}{8}$ in. of aperture. The light of Iapetus is (from some cause at present imperfectly understood) variable. This satellite is very markedly brighter when at its western elongation.

Such are the most salient features of this wonderful planet, as seen in a small telescope. I can only express a hope that my description of them may set the student seriously to work examining them for himself, with the best instrumental means he can obtain. The interest which the contemplation of so wonderful and beautiful an object must perforce excite will, almost of necessity, induce a desire for fuller information concerning it. For such information, of a practically exhaustive character, no better or more interesting a work could possibly be found than 'Saturn and its System,' by the editor of 'Knowledge,' which has been described, with perhaps as little flattery as ever appeared in a critique, as 'one of the most masterly monographs on an astronomical subject in the English language.'

CHAPTER X.

URANUS AND NEPTUNE.

In one sense these chapters would be incomplete were no reference made in them to the aspect in our instrument of the (as far as is at present known) two outermost members of our solar system. A three-inch telescope is hardly the one which the observer would select for the scrutiny of these dim and distant orbs; but, if we are to view them at all, we must employ the optical means at our disposal, and make the most of what we possess. Uranus is now[1] coming into a favourable position for examination. He is so close to β Virginis as to be well within a tolerably low power field together with that star. Even with a power that will include the star and the planet in the same field a very notable difference in their aspect is perceptible; but we must use all the magnification that our telescope will admit of to see Uranus to the greatest advantage; and under such a power he was absolutely isolated in the field of view when the subjoined drawing was made.

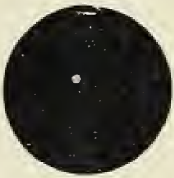

Fig. 35. — Uranus, March 16, 1884, 9h. 15m. G.M.T. Power, 250.

It will be seen that the planet exhibits the appearance of a small greyish-blue disc, seemingly perfectly uniform in tint, and without markings of any kind. That the disc, however, is planetary and not stellar is evident enough with the power we are using, and may be rendered even more

[1] This was written in March 1884.

apparent by turning the telescope on to β Virginis, and comparing the two images. The difference between the pale diffused disc of Uranus and the sharp and brilliant one of the star, with its single diffraction ring (wholly wanting, of course, in the former), will instantly strike the eye. That, however, much more will ever be found out as to the physical aspect of the planet is—in the existing state of practical optics—doubtful. Light itself, travelling at the rate of nearly 187,000 miles in a second, takes more than 2 hours and 28 minutes to pass across the stupendous interval which separates us from this remote world when he is in opposition to the sun. The student will have read that Uranus is attended by four satellites; but it is quite needless to add that they are utterly beyond the power of the telescope we are employing. Probably no human eye, save one, has ever seen these extremely minute objects with less than about 7 inches of aperture, the solitary observer to whom I refer being that excellent and almost supernaturally keen-sighted one, Mr. I. W. Ward, of Belfast, who did actually glimpse the two outer satellites with only 4·3 in. of aperture on many occasions during the early part of the year 1876! The reality of this quasi-miraculous feat was placed beyond doubt by the subsequent comparison of Mr. Ward's diagrams made at the telescope with Mr. Marth's calculated ephemerides of the satellites. Uranus, I may add, is just visible to the naked eye. Of Neptune little need be said. He will be well placed next November for the observer in Taurus, about 6° south of the Pleiades. In a three-inch telescope, with a power of 250, he looks something like an eighth magnitude star; but, as in the case of Uranus, he exhibits no diffraction rings and is dimmer than an ordinary fixed star. It, however, requires a large and powerful telescope to exhibit Neptune with an unmistakably planetary disc, and the observer with an instrument of the size of that whose use is presupposed in these pages may be contented if he can fairly satisfy himself that it is not a star that he is looking at.

CHAPTER XI.

DRAWING THE PLANETS.

PROBABLY in no way could our knowledge of the physical structure of the planets be more effectually advanced than by the comparison of numerous carefully executed and accurate sketches of their superficial detail, made at sufficient intervals; and very notably does this apply to the three bodies immediately exterior to the earth—Mars, Jupiter, and Saturn. It is more especially, then, to facilitate the delineation of these particular planets that the present chapter is written. I do not, however, mean here to enter into the question from an artistic point of view; all I propose to do is to instruct the student how to draw the *outlines* of the planets with ease and accuracy; as this always forms a stumbling block in the way of the beginner. Commencing with Mars, he is, at present,[1] sensibly circular, and subtends an angle of some 17″. Hence we need only take a pair of compasses, and with centre C′ (fig. 36) and a radius C′A or C′D of half an inch, describe a circle A C D B—of course 1 in. in diameter—to obtain the outline we require. But Mars is sufficiently near to the earth to exhibit a sensible phase, and when near 'quadrature' with the sun is very perceptibly gibbous—or like the moon about a couple of days

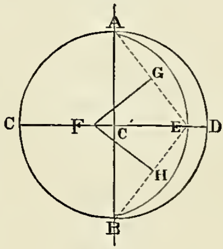

Fig. 36.

[1] This was written in February 1884.

before or after she is full. Suppose, then, that we wanted to draw the outline of Mars on May 15, 1884. Turning to p. 468 of the 'Nautical Almanac,' we find that only 0·9 of that diameter of the planet passing through the sun is illuminated (this is not a strictly scientific description, but will be better understood than 'the versed sine of the illuminated portion of the disc'). Let C D be this diameter, and A B one at right angles to it. Then C E will be the part in light. First,

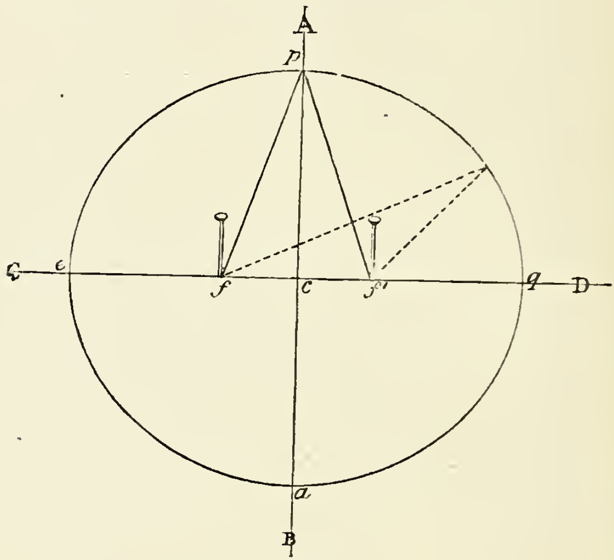

Fig. 37.

with centre C′ as before, and radius C′D, describe the circle ACBD. Measure off one-tenth of C D to E. Join A E, B E, and bisect A E in G and B E in H; from G draw G F at right angles to A E, and from H, H F at right angles to B E. Finally, from F, where these last two lines intersect, and with radius F E or F A, describe the arc A E B. Then will A E B C represent the outline of Mars at our specified period.

If now we try to draw Jupiter as we see it in the telescope, we perceive at once, from its pronounced elliptical outline, that it is impossible to do so, merely by the aid of compasses, at all. The equatorial diameter of Jupiter just now [1] approaches 43″, so that, adhering to our original scale, we may represent this in fig. 37 by eq, which we must make equal to 2·4 in. The preface to the 'Nautical Almanac' tells us that Jupiter's polar diameter is only ·939 of his equatorial one, so that we take $p\ a = 2·25$ in. Then from the centre c, where the two diameters cut each other (of course, at right angles), we take the distance $c\ e$ or $c\ q$ in the compasses, and placing one leg of the compasses on p or a, move them about until the other leg touches the line $c\ q$ in the points f and f'. Into these points, technically called the *foci* of the ellipse, we stick two pins, and round them tie a loop of thread of such length that when stretched tight by a pencil, the pencil point shall just touch either a, e, p, or q. $f\ p\ f'$ represents this thread in our figure, and if it be kept tightly stretched as the pencil is carried round, the curve $p\ e\ a\ q$ will be the correct elliptical outline of Jupiter to our adopted scale.

The description of the outline of Saturn and his rings only involves a repetition of this process. Its successive steps will be understood by the study of fig. 38.

As the diameter of Saturn was 17·8″ on January 14 of the present year,[1] we revert to our original scale of 1 inch for the equatorial diameter of the planet. But he is even more elliptical than Jupiter, his polar axis only measuring ·895 of that passing through his equator; so, to begin with, we have $e\ q = 1$ inch, and $p\ a =$ ·895 inch. As before, with one leg of the compasses on p or a, and with the distance $c\ e$ or $c\ q$, we find the foci $f\ f'$, and describe the outline of the ball of the planet. From p. 468 of the 'Nautical Almanac' we ascertain that, at the epoch chosen, the outer major axis of the outer ring $o\ d$ was 44·62″, and its outer minor axis $i\ d'$ 19·11″; converting these into linear measure by a rule-of-three sum, we find $o\ d = 2·5$ inches,

[1] This was written in February 1884.

and $i\,d' = 1{\cdot}07$ inch. In like manner we find that the inner major axis of the inner ring $o'\,d''$ was $29{\cdot}67''$, and its inner minor axis $i'\,d'''$ $12{\cdot}71''$; quantities which, as before, we turn into $1{\cdot}66$ inch and $0{\cdot}72$ inch respectively. Then, in the manner explained two or three times previously, we find the foci f^2, f^3, and f^4, f^5, insert our pins, and describe the ellipses to which they respectively pertain; the result being shown in our figure.[1]

Possibly by this time the beginner who has followed me so far may feel tempted to exclaim, 'Good gracious! am I to go through all these elaborate reductions of angular

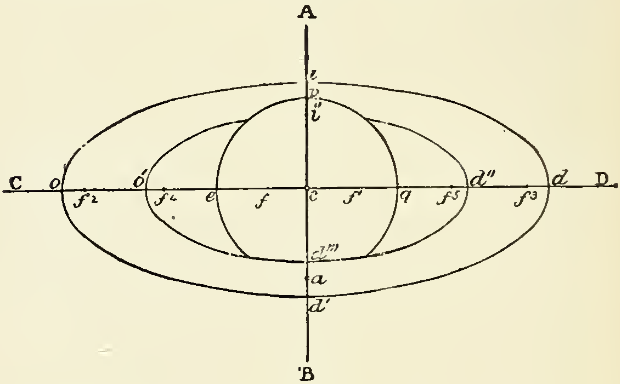

Fig. 38.

into linear measurements, these findings of foci, sticking in of pins, carefully tying loops of thread of a rigidly accurate length, and all the rest of it, every time I want to make a drawing of Jupiter or Saturn?' To which I would reply, 'Certainly not.' The outline of Jupiter is, for our present purpose, absolutely invariable, while those of Mars, and especially those of the Saturnian system, vary so slowly that the outline once drawn will be sufficiently accurate for

[1] The relative dimensions of the Saturnian system given in the 'Nautical Almanac' are notably erroneous; but they are, at present, the best available.

many weeks. All, then, that the student has to do is to transfer such outline to a sheet of what is called in the shops latten-brass, and, cutting it very carefully out, to thus make a stencil-plate. This is held firmly down on to the paper, and very thick Indian ink rubbed over and round it with a stencil-brush or tooth-brush with the hairs cut short, the result being a white figure of the planet on a black background. If latten-brass cannot be procured card may be used, but the brass will be found the more satisfactory of the two. Furthermore, for the mere purpose of obtaining an outline, a sharp-pointed pencil may be run round the edges of the stencil-plate, although the Indian ink will be found much more effective. In this way I have myself for some years past prepared outlines of the planets for the purpose of sketching, with results so successful that I unhesitatingly recommend it to all who may care to address themselves seriously to the very interesting task of delineating the detail visible on the surfaces of our nearest neighbours

CHAPTER XII.

THE FIXED STARS AND NEBULÆ.

NIGHT ONE.

IN treating of the fixed stars in this concluding chapter, I propose simply to select a moderate number of typical and interesting objects for description and illustration, and to take them from all parts of the sky visible in Great Britain. I am not writing for the possessor of an equatorially mounted telescope, furnished with graduated circles. To any one possessing these means of identifying objects, the stellar heavens present an inexhaustible storehouse of objects of interest: but I am here addressing the owner of a three-inch telescope, mounted on a simple pillar-and-claw stand. I shall, then, merely direct the attention of the student to certain stars, &c., marked in the maps of 'The Stars in their Seasons,' in the 'Knowledge' Library Series, with a probably rare reference to Proctor's 'Star Atlas.' Now let us open Map I. of 'The Stars in their Seasons,' and towards the lower right-hand corner we shall find a star in Cetus, marked γ. If we are employing the little device illustrated in fig. 1 (p. 3), we must take care that the bar B M is as duly north and south as we can place it, and this adjustment being made, we put on our lowest power eye-piece, and find γ Ceti in the sky. Having got it into the middle of the field, we exchange

Fig. 39.—γ Ceti.

the low power for one of 160, and examine our object. At the first glance, probably, the student will see nothing but a yellowish star of considerable brightness: but, by careful attention, he will not be long ere he catches its small companion, seemingly to the left of, and just below a horizontal line passing through the larger star. Its blue or dusky tint will at once strike the observer, as well as its small size compared with that of its primary. This elegant pair form what is known to astronomers as 'a binary system;' in other words, the stars are physically connected, and the smaller star revolves round the larger one—or both round their common centre of gravity—in a very long period, the exact duration of which is, as yet, undetermined. There are other objects of interest in Cetus, but the difficulty of identifying them compels me to omit reference to them. Among them, 66 Ceti may be mentioned as a charming pair. It may be found—with numerous other doubles—on Map III. of Proctor's 'Star Atlas.'

Above, and to the right of that part of Cetus in which γ is situated, will be seen a curved line of three stars, the chief ones in Aries; the bottom, and least, of which is remarkable as being the one of which Hooke wrote in 1664, 'I took notice that it consisted of two small stars very near together; a like instance to which I have not else met with in all the heavens.' It is almost needless to tell even the beginner that double stars are now numbered by thousands. Viewed with a power of 160, γ Arietis presents the appearance shown in fig. 40. The components of this asterism will be observed to be pretty nearly equal in size. The (apparently) lower and smaller star of the two will be seen to be of a greyish hue. If now the observer will follow an imaginary line from γ through β on the map, it will strike upon a star, not lettered there, but fairly well seen with the naked eye to the

Fig. 40.—γ Arietis.

right of α. This is λ, a wide but pretty double. Here again the smaller star is more distinctly coloured than the larger one. Forming the apex of a right-angled triangle with α and λ Arietis (whereof α is at the right angle) is a wide triple star, 14 Arietis. Sweeping where Aries and Triangula are conterminous, several pairs of small stars will pass across the field of view. Some 2° (four times the diameter of the sun or moon) above and to the right of β Arietis (as seen by the naked eye) will be found a beautiful close double star, which will most severely tax the power of the incipient observer to see it fairly separated. It is 179 of Hour I. in Piazzi's great catalogue. The yellowish tinge of the larger component, contrasting with the blue of the smaller one, renders this a very pretty object. And now the observer may raise his telescope higher still, to that lovely object γ Andromedæ (above Triangula in the map). The contrast between the yellow of the large star and the exquisite green of its small companion is very striking. π Andromedæ, to the right of β, is a very pretty pair, the contrasting colours being, in this case, very pale yellow and blue; 59, Σ 3, P. XXIII. 240, and other beautiful pairs, will be found marked in Proctor's 'Atlas.'

Exchanging now his high power for the lowest one supplied with his telescope, the beginner should fish a little above and to the right of ν Andromedæ for that most remarkable object, 31 of Messier's catalogue; the well-known great nebula in Andromeda. Sir John Herschel quotes Simon Marius as describing the appearance of this nebula as resembling that of a candle shining through horn, and this really does not give a bad idea of it as viewed in such an instrument as that which we are using. Readers of current scientific literature will remember how a new star shone up in the very midst, and close to the nucleus of this nebula, in August 1885, and which faded to invisibility early during the present year (1886).

None of the larger stars in Taurus present any features of interest in small telescopes. χ Tauri is a somewhat wide,

but pretty pair. In the Map I. of 'The Stars in their Seasons,' which we are supposed to be using, a trapezium of small stars will be noted above the words *Aldebaran* and TAURUS. χ is at the left-hand top corner of this trapezium. Identification of the smaller ones without graduated circles is almost hopeless ; using a low-power eye-piece, though, the Pleiades present a fine spectacle, and about two diameters of the moon above and to the right of ζ Tauri will be found a pale elongated nebula. A low eye-piece too must be used for this. Nearly overhead (in December and January), Perseus will be observed—a constellation rich in objects of interest, of which, however, I can only give an account of a very few suitable for the instrument whose employment is presupposed. ϵ is a very fine pair, but the smaller star requires some little looking for. It is below and *just* to the right of its primary. It is delineated in fig. 41.

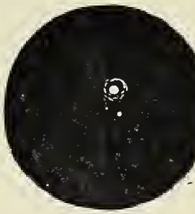

Fig. 41.—ϵ Persei.

ζ Persei is really a quadruple star, but the student will scarcely discern more than three out of its four components with the aperture I am considering. η is another pretty pair, too, but somewhat difficult from the faintness of its companion. Perseus contains several interesting clusters—notably one of the most glorious fields of stars in the whole heavens, in what is called the 'Sword-handle.' This may be seen by a sharp-sighted person with the naked eye, between Perseus and Cassiopeia, as a bright spot in the Milky Way. This superb object requires the lowest eye-piece in the observer's possession, to do it the smallest justice. No view of it, however, with so small an aperture, will give any idea of the gorgeous effect it presents in a large instrument.

South of Aries and the Pleiades lies the straggling constellation Eridanus. It contains numerous interesting pairs of stars, which, in the absence of Proctor's 'Atlas,' must be swept for. It would only tend to confusion to attempt to localise them on a map in which they are not lettered nor

numbered. 32, 39, 55, and P. III. 98, will all be found to be beautiful and attractive objects, and are marked in Proctor. A curious planetary nebula, ♅ IV. 26, seen best with a tolerably low power, will be found there too.

Night Two.

By this time the student will have become tolerably familiar with his instrument. I propose to employ it to-night in the examination of some of the more striking objects in the glorious constellation of Orion. And first we will turn it upon β Orionis or Rigel, fig. 42, which will furnish the young astronomer with good, if easy, preliminary practice in the detection of small stars in the neighbourhood of larger and more brilliant ones. Probably, at first, his eye will be dazzled with the brilliant blue coruscations surrounding Rigel itself; but a little careful attention will show just above and to the left of it a small bluish point, as shown in the figure. From Orion's foot he may proceed to his face, in which we shall find λ, a very pretty pair, tolerably close together, the larger star being yellowish, the smaller

Fig. 42.—Rigel.

Fig. 43.—λ Orionis.

one more of a lilac hue. Fig. 43 represents it as seen with a power of 120. The lowest, or most easterly of the three stars in the Giant's belt, ζ, will next claim our attention, and to show this properly will be a pretty severe test of the excellence of the observer's instrument. As shown in the drawing below, this star is triple; the principal and second

stars, with a power of 150, being almost in contact, and the third below and to the right of them. Some considerable gazing will be required on the part of the beginner before he succeeds in making out the duplicity of the principal pair in this asterism. The engraving may help him to understand exactly what to look for.

Fig. 44.—ζ Orionis.

Fig. 45.—σ Orionis.

We now turn to σ, which will be seen beneath ζ in the map. This is a triple, or, perhaps more correctly, a septuple star, all the components shown in fig. 45 being well within the same field with a power of 120.

The object marked θ in the map is one of the most wonderful in the whole heavens, consisting, as it does, of a mass of nebulous matter (now known to be glowing gas!) surrounding, and seemingly physically connected with, a curious group of stars.

Fig. 46.—θ (and 42 M. Nebula) Orionis.

No woodcut can possibly do justice to this most marvellous object: but in my sketch, copied above, I have endeavoured to give some faint idea of its aspect as viewed with a power of 80. The black gap leading up to the trapezium of four stars is known as 'the fish's mouth.'

The nebulosity surrounding an isolated star, towards the bottom of the field, will be noted. The difference in colour of the stars forming the trapezium will be readily detected. There are a fifth and a sixth belonging to this group; but they are entirely beyond the power of such an instrument as that which we are using.

Having gazed our fill on this wonderful sight, and, furthermore, particularly scrutinised the trapezium of stars with the highest power at our disposal, we will lower the telescope a little to ι Orionis, a very pretty triple, in a fine field.

Its aspect, as seen with a power of 120, is shown in fig. 47. The smallest of the three stars will require careful looking for before the unpractised observer will see it at all.

Fig. 47.—ι Orionis.

Fig. 48.—ρ' Orionis.

Fig. 49.—52 Orionis.

An even more difficult star is ρ^1 Orionis, represented in fig. 48. This will require a power of 150 at least, and, in fact, as high a one as the observer possesses, to see the companion fairly. The small star is so faint and difficult with a three-inch aperture as to form a very fair light-test indeed. ρ^1 may be found by carrying an imaginary line through the three stars ζ, ϵ, and δ, in the belt, on which line, at double the length of the belt from δ, it will be found.

The last illustration I shall give is of 52 Orionis, a severe test of the separating power of such an instrument as I am considering. At moments of the finest vision, with the

highest power at the observer's disposal, it will be seen as in fig. 49.

Such are a few typical stars among a very mine of such objects in which the student may well search by sweeping for himself. Should he succeed in exhausting such a treasury in one night's work, he may turn his telescope down to Lepus, where, *inter alia*, he will find a pretty, and somewhat difficult pair in κ. This is the star to the right of λ, and just beneath ι, in Map I. of 'The Stars in their Seasons.'

Night Three.

In speaking of Taurus on p. 89, I omitted one object in the absence of means for its identification. It was 118 Tauri, which is a beautiful small pair; it lies below β on the map. In noticing the nebula to the north-west of ζ Tauri, I omitted, too, to add that ζ itself is situated in a rather pretty and curious field.

Above Taurus lies the constellation Auriga, to the examination of which we proceed to devote ourselves. I will begin with 14, a star just above a line joining β Tauri and ι Aurigæ in the map, and about halfway between them there. Really triple, we shall only be able to see it as a double star, the components being of a yellowish tint, and about half as far again apart as those of γ Arietis. A very pretty pair will be found in ω Aurigæ. This does not appear by name on the map, but is about halfway between η and ι It is represented in fig. 50.

Fig. 50.—ω Aurigæ

Fig. 51.—θ Aurigæ.

θ Aurigæ, as a close and very unequal pair, will tax both the instrument and the eyesight of the observer to the

uttermost to see it properly. When best seen it will appear as in fig. 51.

5 Aurigæ (to the south of ζ) is another star in which the diversity of size of the components and their proximity render its observation decidedly difficult. The student will see both these objects better with a high power than with a lower one. 26 (N.E. of β Tauri in the map) is a pretty star, from the contrasted colours of its components, and is very easy from their distance. The companion is almost horizontally to the left of the larger star. Σ 872 is an equally easy pair. It will be found just to the left of the solstitial colure in the map. 225 P. v. Aurigæ, to the N.E. of 26, must be found by fishing, as it is invisible to the naked eye. When in the field of the telescope, however, it will be found to be a close and extremely pretty little pair.

We may now take a glance at two or three of the most striking clusters of stars in the constellation under review. And first, M. 38 (north of ϕ Aurigæ) forms a beautiful field, the main cluster assuming a cruciform aspect. The telescope may be moved about in this neighbourhood, which is a rich one. M. 36 (nearly due E. of ϕ) is also very fine. M. 37 (N. of the double star 225, previously described) is a glorious field, even with such an instrument as that which we are employing. In regarding a nebula or cluster, no light should be suffered to enter the eye for some little time before it is applied to the telescope; and the observer should gaze steadily at such an object until the eye becomes accustomed to it, after which hitherto imperceptible detail will flash up. Another rich field will be found in H VII. 33 (N.E. of μ in the map).

Our next object to-night shall be that beautiful and familiar double star α Geminorum, or Castor (Map II. of 'The Stars in their Seasons'). This, with the instrument we are employing, we shall find to be a perfectly easy object; in fact, were the young observer furnished with the means of accurately directing his telescope, Castor might be seen

double in bright twilight—or even in broad daylight. Its telescopic aspect, with a power of 120, is shown in fig. 52.

δ Geminorum is another star which will repay examination. It will be found in Map II. The small purplish companion will be seen above the principal star, and just to the left of the hour circle passing through it. κ (below Pollux in the same map) is a difficult and delicate pair, requiring a first-class instrument and acute vision to see the comes at all. 38 in this constellation, though difficult, is a decidedly easier object than κ. In both these stars the contrasted colours of the companions are very fine. Many other objects will be found, but, being invisible to the naked eye, they are by no means easy to pick up without an equatorial mounting.

Fig. 52.—Castor.

Fig. 53.—66 Cancri.

Cancer is not a constellation containing many objects of interest within the power of a three-inch telescope. Nevertheless the student will see ζ as a double star (it is really triple). ϕ^2 is another object, approximately as easy to see as ζ. 66 Cancri is decidedly more difficult; for, although the components are about the same distance apart as those of ϕ^2, their considerable inequality makes the comes look small by contrast. Fig. 53 exhibits it as seen when best defined with a power of 160.

ι Cancri is chiefly interesting from the contrasted colours of its components. They are, relatively, very wide apart. Should the observer possess a day eye-piece, he may put it on to scrutinise the Præsepe with. At all events, he must use the lowest power he has. The same eye-piece may be

retained to look at another cluster, 67 Messier, somewhat to the west, or right, of α in the sky.

And now we arrive at a star which, while scarcely affording a crucial test, yet requires a very good eye and instrument to see it well and cleanly separated. I refer to the familiar one, γ Leonis (Map III. 'The Stars in their Seasons'), which, with a power of 160, should present the appearance indicated in fig. 54.

A more difficult object, and one which will severely tax the powers, both optical and visual, of the observer, is ι Leonis (Map III.). 54 Leonis is a charming object. There are a very great many small pairs in Leo; but the remarks which I have made above in connection with telescopic stars in Gemini are equally applicable here. If the student will fish about the apex of an equilateral triangle, whereof α and γ Leonis form the extremities of the base (to the left, or east, of the line joining them), with the lowest power at his disposal, he will find himself in a region rich in nebulæ.

Fig. 54.—γ Leonis.

Underneath Leo in the maps will be found the foolish modern constellation of the Sextant. 35 Sextantis (about 5° S.E. of ρ Leonis) is worth looking at, as a curious disagreement exists as to the colour of the comes. There is a bright nebula, too, worth examination, in Sextans. It is 163 of Sir William Herschel's first catalogue.

Hydra, straggling across the sky beneath Cancer, Sextans, Crater, Corvus, Virgo, and Libra, contains a considerable number of interesting objects, though but few of them are susceptible of easy recognition. ϵ Hydræ is a fine pair, but difficult with such an instrument as we are employing, on account of the proximity of its components, and of their disparity in size. Of the objects in Crater and Corvus (two figures perched by the map-makers on Hydra's back), I need here only allude to 17 Crateris, an easy double star, with prettily contrasted colours; and to δ Corvi, wider

apart still, but exhibiting even more prominent tints in its components. About three-quarters of the way upon an imaginary line drawn from α to δ Corvi will be found a nebula, 65 of Sir William Herschel's first catalogue. By this time the incipient astronomer will probably feel that he has accomplished a fairly good night's work. Our next night we will devote to Virgo and the neighbouring region of the sky.

Night Four.

Before beginning our examination of the constellation Virgo to-night, I will return to that of Hydra for the purpose of looking at a very wonderful object, omitted in the description on the preceding page. The student will find it by fishing with a power of 100 or so about 2° (four diameters of the moon) to the south of μ Hydræ (Map III.). It is No. 27 of Herschel's fourth catalogue, and is one of the most remarkable planetary nebulæ in the heavens. Unlike nebulæ generally, this will bear considerable magnifying power. It will be seen as a pale blue disc, looking just like the ghost of Jupiter. As Huggins has shown that it is gaseous, the sharpness of its outline is very curious.

Fig. 55.[1]—γ Virginis. Fig. 56.—ϵ Bōotis. Fig. 57.—ξ Bōotis.

Turning now to Virgo, I will begin with that most interesting star γ, which is shown in fig. 55, as seen with a power of 160. When first observed by Herschel, in 1790,

[1] The letters S and N in this and subsequent figures indicate the South and North parts of the field of view; while the arrow shows the apparent direction of the star's diurnal motion.

the components of this star were nearly 6″ apart, but were approaching each other; and in 1836 were so practically superposed as to appear single under the very highest power that Admiral Smyth could apply to them upon his 5·9 inch achromatic. Since that time they have been separating, and their distance at present amounts to about 5″, so that they form an easy pair in the instrument we are using. θ Virginis (Map. V.) is a very pretty and interesting triple; the third star, which is nine times as far from the large one as its more obvious companion, will require a dark night and pretty sharp sight to see it well. There are very many beautiful and interesting pairs of stars in Virgo; but as they are mostly below the sixth magnitude they are not marked in the maps whose employment I am presupposing, and no amount of description would enable the reader to identify them. Fortunately, simple sweeping, in the marvellous region to which I am about to introduce the reader, will suffice to enable him to pick up many of the wonderful mass of nebulæ collected within the area roughly bounded by ϵ, δ, γ, η, and β Virginis, and β Leonis. If the student will arm his instrument with a power of about 40, and sweep slowly over that part of the sky contained within the curve drawn through the stars I have named (Map V.), he cannot fail to be astonished and pleased at the wealth of nebulous objects, and the pretty fields of stars that he will encounter. One of these curious objects is shaped like a boy's kite. A few are resolvable into stars in some of the enormous telescopes now comparatively common. Others are unmistakably gaseous.

Above Virgo is situated Coma Berenices, easily recognisable in the sky by the coarse cluster of stars in its north-western portion. If the reader will draw an imaginary line from α through 36 on Map V., then at about three times as far to the right of 36 as 36 is to the right of α, and a little above such line, will be found 24 Comæ, a wide double star, but interesting from the beautiful contrast of orange and pale purple presented by its components. Just above, and

to the left of α Comæ (Map V.), what will appear like a nebula will be found. It is 53 of Messier's catalogue, and is really an immense mass of tiny stars; but it requires a much more powerful instrument than ours to show this. Other nebulæ, mostly faint, will be found among the cluster of stars to which I have previously referred.

Adjoining Coma Berenices above lies Canes Venatici, of which the chief star, α, 12, or Cor Caroli—for it has all three designations—is a widish double. About one-third of the way between Cor Caroli and δ Leonis 2 Canum will be found—a close pair, with prettily contrasted colours. There are numerous other pairs in this constellation, but, for the so often reiterated reason, I can give no intelligible directions for finding them. In the case of more than one of the remarkable nebulæ, however, contained in it, I trust to be more successful in pointing out their whereabouts. 3° (6 diameters of the moon) to the south-west of η Ursæ Majoris, the star at the end of the Great Bear's tail, will be found two rather dim nebulæ, nearly touching each other. This is Messier 51, the astonishing Spiral nebula, which, as seen in Lord Rosse's great telescope, has been pictured in so many works on astronomy. About midway between Arcturus and Cor Caroli, but rather nearer the former (Map V.), will be found a bright nebula, Messier 3, which large telescopes resolve into a brilliant condensed cluster of minute stars. Some $2\frac{1}{2}°$ to the north-west of Cor Caroli is a nebula, 94 Messier, which, though small, is sufficiently conspicuous in the class of instrument we are using. Other nebulæ in this constellation may be picked up by fishing, especially in the region between α Canum Venaticorum and ξ Ursæ Majoris.

The constellation Böotes, at which we now arrive (Map VI. of 'The Stars in their Seasons'), will be found a very mine of objects of interest by the incipient observer. We will begin by turning our instrument, armed with a power of 160, upon ϵ, a star which Struve well described as 'pulcherrima' (or most beautiful). So viewed it will be seen as in

fig. 56, the larger star being yellow, and the companion a bluish-green. π Böotis, an interesting and easy pair, when viewed with a power of 160 will be found to present the appearance shown in fig. 58. ξ Böotis is a little closer and somewhat more unequal pair, the colours of the components, moreover, being more strongly contrasted than in the case of the previous star. It is shown in fig 57. ι is a wide and easy pair, which it is needless to figure. 44 Böotis, shown in fig. 59, as seen with a power of 160, is interesting from the contrasted colours of its components. It is not numbered in the map, but is one of two small stars forming a triangle with β and θ Böotis in it. Nor is

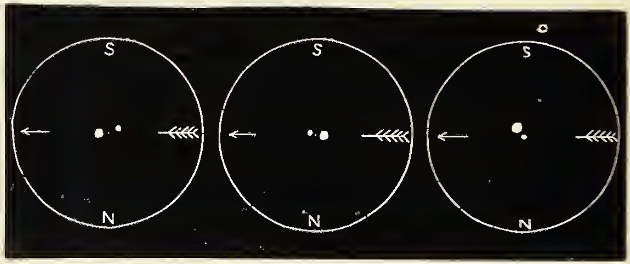

Fig. 58.—π Böotis. Fig. 59.—44 Böotis. Fig. 60.—39 Böotis.

our next object, 39 Böotis, numbered; but it is the north-western of the pair of stars in the map, and will be found in the sky, a little above, and to the right of 44. In this, again, the colours are prettily contrasted. Its aspect as viewed with the same power as the preceding objects is represented in fig. 60. κ Böotis, on the confines of Canes Venatici, is a wider, and much more unequal pair. It is shown in fig. 61. On a line drawn from Spica Virginis to ζ Böotis, and about 11° south (and a little east) of Arcturus, will be found the very pretty and interesting double star which I have drawn in fig. 62. It is 69 of the fourteenth hour of Piazzi's catalogue. The difference in colour of the components of this pair will at once strike the observer. He

will, though, probably be puzzled to say exactly what the colour of the smaller star is, very discrepant conclusions on this subject having been arrived at. Some $8\frac{1}{2}°$ to the west, and just to the north of Arcturus, we shall find a very beautiful object, the star ι Böotis, shown in fig. 63. At the first glance the student will observe two stars, nearly of the same magnitude, and wide apart. It is the upper, or southern one of them, to which our attention must be directed. Looking at it carefully, we shall note the minute blue star shown in fig. 63, to the south, and very slightly to the east of its primary. I have omitted the second large star of which I have just spoken from the diagram,

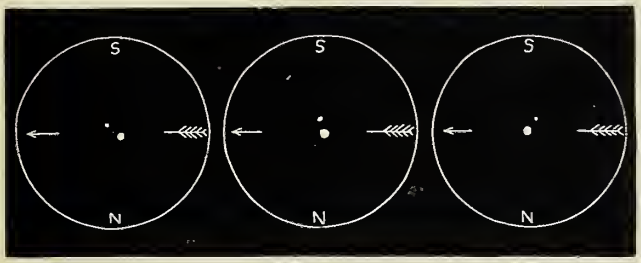

Fig. 61.—κ Böotis. Fig. 62.—P. xiv. 69. Fig. 63.—ι Böotis.

inasmuch as, using the scale to which it is drawn, such star would be just out of the northern, or lower, portion of the field. Finally, the student may, if he likes, look at ζ Böotis with the very highest power at his command ; but, under the most favourable circumstances, he will only succeed in so far converting it into a slightly egg-shaped object as to show that it is not single. Such are a few of the most easily identifiable objects in this constellation. The number of purely telescopic double stars is very large indeed ; but their necessary absence from our map of reference, and the impossibility of recognising them without an equatorial provided with graduated circles, renders the mere mention of them here sufficient.

NIGHT FIVE.

To the east of Böotes lie the constellations Corona Borealis and Serpens, which we will to-night proceed to examine. Beginning with the former (which really does present more than the ordinary resemblance to the object whose name it bears), we shall find a very interesting double star in ζ (Map VI. of 'The Stars in their Seasons'), the components exhibiting well-contrasted colours. Its aspect, as seen with a power of 160, is shown in fig. 64. σ Coronæ is a very pretty pair. It is delineated in fig. 65, as viewed with the same power as the last star. σ will be found in the sky, as nearly as may be, 10° N.E. of α Coronæ. This is sometimes ranked as a triple star, as the pair shown in the subjoined sketch are followed, at a distance of 51″ or 52″, by a minute blue star. σ itself is one of what are known as binary stars, i.e. physically connected pairs ; and, in the description of their orbits about their common centre of gravity, its components have separated from 1″·3 in 1830, to something like 3″·5 now.

Fig. 64.
ζ Coronæ Borealis.

Fig. 65.—σ Coronæ Bor.

Fig. 66.—δ Serpentis.

One of the most interesting of these binary systems, that of η Coronæ, is, unfortunately, quite hopelessly beyond the power of our instrument, as the two stars are now less than 0″·7 apart. Their distance varies from about 1″·4 to 0″·3, and their orbit is described in something over forty years. There are several pairs of telescopic stars in this constellation, all of them tolerably easy to divide, but it is very

difficult to give directions for finding them, in the absence of an equatorially mounted telescope with divided circles. An easy one (Struve 1964) will be found a little to the south-west of ζ, described above. While going over Corona the student should not omit to glance at that most astonishing object, T Coronæ, the star which blazed up suddenly as a second magnitude one in the year 1866. Examined by our greatest English spectroscopist, Dr. Huggins, on May 16 in that year, it was found to exhibit a double spectrum; one analogous to that shown by our own sun, the other one that of glowing gaseous hydrogen, thus (possibly) indicating a conflagration on a stupendous scale. Subsequently to this the star faded to the 9th magnitude, revived again somewhat, and has since been irregularly variable. At present it appears as a star of about the $9\frac{1}{2}$th magnitude. It is situated on an imaginary line drawn from ϵ Coronæ to π Serpentis, at rather less than one-third of the distance between the two from ϵ.

Serpens, to which we shall next devote our attention ('The Stars in their Seasons,' Map VII.), is one of those straggling and sprawling constellations so difficult to follow in the sky. Nevertheless, it is one containing many beautiful and interesting objects. To begin with, α is a very wide and unequal pair, the smaller component requiring a good deal of looking for with a small telescope. I mention it here for the pretty contrast in colours which it presents. δ Serpentis, shown in fig. 66, is a very neat and pretty binary star; the components are at present separating. β is, like α, a widish and very unequal pair, the small star, as in the former case, being bluish. θ Serpentis is comparatively wide and easy. It will well repay examination, though, from the richness of the region in which it lies. γ Serpentis, 4° north-east of η, is also wide and easy. As before, I mention it for the pleasingly contrasted colours of its components. 5 Serpentis, 9° south-west of α, is much closer, and very unequal; it will repay examination. $10\frac{1}{2}°$ to the north-east of α Serpentis, on a line drawn from that star to

Vega, will be found 49 Serpentis—a fine pair shown in fig 67. This is a binary system, with a supposed period of 900 years ! 59 (or *d*) Serpentis is a beautiful object, the colours of its close and unequal components being strongly contrasted. It is represented in fig. 68. Smyth's directions for finding this star are, perhaps, as good as any. 'To identify 59 Serpentis,' he says, 'let an east-south-east ray be shot from β Herculis through α, which will be found two-fifths of the way' (i.e. from β Herculis to 59 Serpentis).

Fig. 67.—49 Serpentis.

Fig. 68.—59 Serpentis.

Fig. 69.—13 M. Herculis.

Libra ('The Stars in their Seasons,' Map VI.), is neither a striking constellation to the naked eye, nor does it contain many objects accessible to the class of instrument we are employing. A small but easy pair of stars will be found in No. 62 of Piazzi's fourteenth hour. It lies 15° east by north of Spica Virginis, or $2\frac{1}{2}°$ south-west of ι in the same constellation. 9° due west of β Scorpii will be found P. xv. 91, a not very close but considerably unequal pair. ι Libræ is a very wide and unequal pair, but worth looking at for its prettily contrasted colours. Just to the north-west of 5 Serpentis, of which I have previously spoken, will be found that fine compressed cluster of very small stars, No. 5 of Messier's catalogue. It is scarcely resolvable in a three-inch achromatic, and merely appears like a nebula, brightening conspicuously towards the centre.

We now arrive at that somewhat unintelligible constellation, Hercules, who appears head downwards in the maps and globes, between the constellations of the Northern Crown and the Lyre ('The Stars in their Seasons,' Map VII.).

As my present object, however, is less to reconcile the configuration of the stars composing this constellation with the counterfeit presentment of an inverted hero, than to select from them curious and beautiful objects, suitable to the instrument we are employing, the map we use will supply all the aid necessary for this purpose. I say all the aid ; but in truth the map which should give the position of a quarter of the interesting objects with which this constellation teems, would have to be a very elaborate and crowded one indeed. I must then, perforce, confine myself to a few of the most easily identifiable. Beginning upon the confines of Corona Borealis, half-way between γ and ξ Coronæ, we shall find 23 Herculis. This is a wide pair, but I insert it here for the marked colour of the smaller star, which will be seen below and just to the right of its primary. ζ Herculis, a remarkable binary star, is quite beyond the power of our telescope—in fact, appears single with the means at our disposal. If, though we fish along a line connecting η and ζ Herculis, about one-third of the way from η we shall light upon an object which will amply repay us for any disappointment we may experience in connection with this. The object to which I refer is No. 13 of Messier's catalogue, and consists of a most glorious globular cluster of stars. How far we shall succeed in detecting its stellar character will depend upon the excellence of our instrument, and the acuteness and training of our vision. I have tried to indicate its character in fig. 69 above. $1\frac{1}{2}°$ north by east of η Herculis will be found another cluster (Messier 92), which the average eye and instrument will only show as a bright nebula. I may further note here that there are two planetary nebulæ in this constellation ; but that only one of these is at all within the reach of a three-inch telescope, and neither can be found with certainty save in one equatorially mounted.

Night Six.

And now we come to the lovely object of which fig. 70 is nothing but a diagram, α Herculis ; the contrast between

the pronounced orange hue of the large star and the emerald green of the smaller one being perfectly charming. δ Herculis is a somewhat wide and unequal pair. I insert it here on account of the extraordinary discrepancies which appear in the descriptions of the colour of its companion by various observers at different dates. This is a star which the observer will do well to watch. ρ Herculis is a close and beautiful double, the colour of the companion being very fine. It is shown in fig. 71. λ Herculis, between δ and μ ('The Stars in their Seasons,' Map VII.), is only a single star, with nothing but its deep yellow colour to render it remarkable; it is inserted here, though, since it may interest the student to look at, or very near, the point in the heavens towards

Fig. 70.—α Herculis.

Fig. 71.—ρ Herculis.

Fig. 72.—95 Herculis.

which our entire solar system is moving at the rate of some 422,000 miles per diem.

One-third of the way from α Herculis towards Vega (the brilliant star in Lyra) will be found a widish pair, 200 of Piazzi's seventeenth hour of R.A. It is noticeable for the beautifully contrasted colours of its unequal components. If we draw an imaginary line from α Ophiuchi to β Lyræ ('The Stars in their Seasons,' Map VII.), and travel 10° along it, we shall arrive at 95 Herculis, a tolerably close star, whose components differ but little in magnitude, although they have been alleged to do so notably in colour. Smyth calls them 'apple green' and 'cherry red.' Another observer describes them as both golden yellow. At present they appear to me of a palish yellow, both nearly of the same hue. 95 is represented in fig. 72. μ Herculis, a wide and

very unequal pair, presents, as do so many other stars in this constellation, very finely contrasted colours. 11° from β Lyræ, on a line joining this star with α Herculis, lies 100 Herculis, a pretty and easy little pair of equal magnitude. It is shown in fig. 73.

Such are a few typical objects among those with which this fine constellation abounds. Purely telescopic pairs fairly swarm in it, and may be picked up everywhere by simply sweeping the sky. At least seven well-determined variable stars, too, are numbered among its constituents; and, in addition to the two clusters of stars of which I have given a short description above, it contains two planetary nebulæ, and many interesting fields of stars. It will prove a very treasure-house to the incipient observer.

Fig. 73.—100 Herculis.

Fig. 74.—μ Libræ.

Fig. 75.—λ Ophiuchi.

Libra, situated beneath a part of Serpens ('The Stars in their Seasons,' Map VI.), need not detain us long. Its two principal stars, α^2 and β, have very distant comites, but can scarcely legitimately be called 'double.' About $5\frac{1}{2}°$ to the south by east of α the observer will find 212 of Piazzi's hour xiv. It is just visible to the naked eye. It forms a pretty but very easy pair with a moderate power. It is really a triple star, but the third component is hopelessly beyond our aperture. μ Libræ is an extremely close pair, but is said to have been seen by Burnham with a $2\frac{1}{2}$-inch achromatic. Its appearance, as exhibited in an English three-inch telescope, is shown in fig. 74. It is not marked in the map to which I have just referred, but will be found a little more than 2° to the north and west of α. About 6° west-south-

west of μ Serpentis will be found Struve 1962 Libræ a pretty and delicate, but not difficult object. The remaining double stars (of which there are a good many) in this constellation are all invisible to the naked eye. Before quitting it we must look at that beautiful object, 5 of Messier's catalogue—a fine cluster of stars crowded into a nebulous-looking object. This lies nearly 9° to the south-west of α Serpentis, and forms a rudely equilateral triangle with that star and μ in the same collection.

Below Herculis, and straggling in and out of Serpens, Libra, Scorpio, and Sagittarius, we find Ophiuchus, or the Serpent-bearer. The Serpent borne by this gentleman I have already described in pp. 103 and 104. I now turn to its carrier himself. Unlike Hercules, the major part of Ophiuchus appears meagre and barren to the naked eye. It, however, resembles that constellation in being replete with objects of telescopic interest. Beginning with ρ^1—which is, by the way, terribly low down—we find a beautiful close pair of stars, with a pretty contrast between the pale yellow of the larger one and the blue of its companion ; the pair forming the apex of a triangle with two other companion stars. λ will tax the observer's powers and those of his instrument to the very utmost. This is a binary star with a period of 234 years ; its components are very slightly opening just now. Fig. 75 gives some idea of it as seen as a merely oval object, with a high power under the finest definition. Some 3° north-west of η a new star blazed out in 1848, subsequently fading to practical invisibility in small instruments. This neighbourhood should be watched. 10° due east of Antares will be found 36 Ophiuchi, a pretty and fairly easy pair. It is too close to the horizon, though, for fine definition in these latitudes. 39 will be found 1° north-west of θ Ophiuchi. It is very nearly as badly situated as the last star. The components are not very close, but their colours are fine. Another star, much better placed, which may be looked at for the colours of its components, is 67, $4\frac{1}{2}$° east-south-east of β Ophiuchi. It is very wide, though. τ, a most interesting

binary object, will, like λ, prove a crucial test for the observer. It will need an instrument of the highest class, a high power, a very sharp eye and an excellent night to do anything with it; and even with these advantages it will only appear like λ, as a misshapen star.

70 Ophiuchi, 6° to the east-south-east of β, is an interesting pair, shown in fig. 76. The colour of the smaller star is believed, with some reason, to be variable. It used to be violet or purple, and is now yellowish. Ophiuchus is remarkably rich in nebulous-looking star-clusters. As they are not marked in our map, the directions for finding them will, I fear, appear somewhat vague. Beginning with 12 Messier, we shall find this about 8° 15′ north-west by west of ε. 10 Messier is nearly halfway between β Libræ and α Aquilæ. 19 Messier lies 7½° due east from Antares. 9 Messier will be found 3° south-east of η Ophiuchi. About 6½° to the south by west of γ lies 14 Messier; while, finally, 23 Messier Ophiuchi, a fine cluster, will be found about 5° north-west of μ Sagittarii.

Fig. 76.
70 Ophiuchi.

Night Seven.

The chief object in the constellation Scorpio, with which I shall begin to-night, α, or Antares ('The Stars in their Seasons,' Map VII.), is a double star, but, save under the most exceptional atmospheric circumstances, beyond the power of a three-inch object-glass. Nevertheless, on a superlatively fine evening, and with the highest power at his disposal, the student *may* pick up the companion as a minute green speck, or wen, attached horizontally to the left of the blazing red disc of Antares itself. ν Scorpii will be seen at first sight as a wide double star, but a little attention will show that the smaller star is not single. β Scorpii is a pretty and easy pair, the contrast of colouring in its components being very pleasing. It is represented in fig 77.

Half-way between this and Antares, the cluster 80 Messier may be picked up. In the instrument we are employing, however, it will be seen as a nebulous object, strongly resembling a telescopic comet. σ is a pretty pair, but terribly near the horizon. If the student will draw a line from Antares to η Ophiuchi, and travel 10° along it from α Scorpii, he will come upon 236 of Piazzi's hour xvi., a pretty little pair, which will repay scrutiny. Closely following 36 Ophiuchi lies 31 Scorpii (this ought really to be 38 Ophiuchi)—a pretty severe test for a three-inch telescope at any time, and, at present, beyond its power.

Adjoining Scorpio to the east is Sagittarius, but this need not detain us long, as only two suitable objects are to be

Fig. 77.—β Scorpii.

Fig. 78.—μ^1 Sagittarii.

Fig. 79.—π Aquilæ.

found in the map which we are employing. These are μ^1, a striking triple star represented in fig. 78; and 22 Messier, a pale nebulous mass half-way between μ and σ Sagittarii. This (like 80 M. described above) is really a cluster, but is irresolvable with means at our disposal.

Aquila, to the north of Sagittarius, is the next constellation we shall examine. Forming an equilateral triangle with ϵ and ζ Aquila is 11, a severe test for the instrument we are employing. The minute companion, 19″ above and to the left of the larger star, will require the highest power at the observer's disposal to see it at all. At the right hand extremity of the base of an isosceles triangle, whereof ν Aquilæ forms the other end and δ Aquilæ the apex, 23 Aquilæ will be found. The comes of this is also a star that

is invisible with any power less than 250 or so. π Aquilæ is a very good test indeed. Fig. 79 shows it as seen at moments of the best definition.

In that pretty little constellation, Delphinus, the only star which need detain us is γ, depicted in fig. 80. The contrasted colours of the components will at once strike the observer's eye.

And next, Lyra will claim our attention ; and, as is only natural, we shall begin by directing our telescope to its brilliant leader, Vega. Here, again, is a severe test, a fine night and a pretty high power being needed to glimpse the comes at all. In fig. 81 I give something of the appearance of this object, but it is impossible to reproduce in black and

Fig. 80.—γ Delphini

Fig. 81.—Vega.

white the vivid blue blazes and the mouldings and twirlings of the diffraction rings which surround the great star. Moreover, the size of the minute companion is exaggerated, or it could not print at all. Not far off we shall find another most interesting object. I refer to the double-double system ϵ^1 and ϵ^2 Lyræ, shown in fig. 82. Between the two pairs lies another minute star, shown in my sketch. There are two others smaller still ; they, however, require a larger aperture than ours to see them at all. ζ Lyræ is a wider pair, but pretty from the contrasted colours of its components. Between β and γ Lyræ, but nearer to the former star, will be found that astonishing object, 57 Messier Lyræ, the so-called 'Ring Nebula.' Fig. 83 is an attempt to give some idea of its aspect as seen with a power of 70, but

wood engraving does not lend itself well to the delineation of nebulæ. η Lyræ is a widish double, but interesting from the contrasted colours of its components.

Fig. 82.—ϵ^1 and ϵ^2 Lyræ.

Fig. 83.—57 M. Lyræ.

Fig. 84.—β Cygni.

We will now turn to that glorious region occupied by Cygnus, in which the merest vague sweeping cannot fail to reveal innumerable objects of beauty and interest. I shall, though, select a few of the most striking ones in it for detailed description, as the student can easily wander over the constellation when he has examined them. I will begin, then, with β, the lovely colours of whose components have always rendered it a favourite with the juvenile observer. Fig. 84 gives an idea of the general aspect of this star. $1\frac{1}{4}°$ north of χ lies another wide, but beautifully coloured pair, 278 of Piazzi's hour xix. Nor is χ itself less beautiful and interesting, contrasted colours again forming its chief charm. ψ Cygni, a close and unequal pair, will require a high power to see it. 2° south-west of ϵ is 49 Cygni, shown in fig. 85; while 3° south of ϵ lies 52, in which the components are a little more widely separated. In both cases, as is common in this constellation, the diversity of colours is very beautiful. If we draw an imaginary line from α through ν Cygni, we shall come upon a star (marked, but not numbered, in 'The Stars in their Seasons,' Map IX.) which must always possess the highest interest for all astronomical students. This is 61 Cygni, the very first of those suns which fill the universe whose distance from the earth was determined by the illustrious Bessel. I need occupy

no further space, in a purely practical chapter like this, than to say that, so stupendous is the interval separating our solar system from this object that light (travelling 186,326 miles

Fig. 85.—49 Cygni.

Fig. 86.—61 Cygni.

Fig. 87.—27 M. Vulpeculæ.

a second) takes something like six years to pass across it ; so that the student whom my description may tempt to look at this interesting object will see it (not as it is to-night, but) as it was six years ago, when the light which enters his telescope left it ! 61 Cygni is shown in fig. 86. Cygnus is so crowded with beautiful fields of stars as to render any selection of them for description difficult ; but the beginner may hunt up M. 39 (roughly, half-way between α and ω Cygni) to commence with. μ Cygni is a very pretty triple, the colour of the close pair presenting a pleasing contrast.

If the reader will fish with a power of 70 or 80 between β Cygni and Delphinus, some 7° south-east of the former star he will strike upon that very curious object, 27 Messier Vulpeculæ—the so-called 'Dumb-bell' nebula, of which ridiculous pictures appear in certain works on popular astronomy. I have done what I can to present a portrait of this nebula in fig. 87.

Night Eight.

Capricornus is the next constellation which will claim our attention. It will not, however, detain us long here, as the objects in it identifiable upon Map IX. of 'The Stars in their Seasons' are not numerous. The first of them is

that beautiful star, ρ Capricorni, represented in fig. 88. The contrast of colour is fine. o^2 is a pretty little pair, sufficiently wide apart to be resolvable with the lowest eye-piece. 30 Messier, with a power of 70 or so, will be seen as a rather dim-looking nebula, with an eighth magnitude star just preceding it (*i.e.*, with an inverting eye-piece, to the left of it) It may be fished for to the left and below ζ Capricorni, just above a line joining ζ with Fomalhaut, and (roughly) at a sixth of the distance.

Aquarius, a large constellation extending from the south-east corner of Aquila over the north and to the east of Capricornus, is replete with objects of interest suitable to the instrument we are employing. Numerous others, too

Fig. 88.—ρ Capricorni.

Fig. 89.—41 Aquarii.

Fig. 90.—ζ Aquarii.

small for inclusion in the maps we are supposed to be using, may be picked up by a systematic search. Proceeding, as is our wont, in the order of Right Ascension, the first object we arrive at is Herschel iv. 1, a very fine specimen of a planetary nebula. Somewhat resembling Uranus, but without his sharp outline, it is rather less than $1\frac{1}{2}°$ to the west of ν Aquarii. Our next object, as it happens, is a nebula too, but of a totally different character. This is 2 Messier, a large, bright, and (for a nebula) conspicuous object. It is about 5° north and only *just* to the east of β Aquarii. About 4° to the east by south of δ Capricorni will be found that delicate little pair, 29 Aquarii, its components lying diagonally across the field. If we draw an imaginary line from δ Capricorni to Fomalhaut, at rather more than one-

third of the distance from the former star we shall come upon even a prettier star still, 41 Aquarii, shown in fig. 89. ζ Aquarii is another beautiful object, closer than either of the last described, but perfectly easy with three inches o aperture and a power of 160. It is shown in fig. 90. τ^1 (just below and to the right of τ^2 in Map X. of 'The Stars in their Seasons') is wide, but very difficult, from the smallness of its companion, which will be glimpsed to the right and a little above the larger star. ψ^1 is another wide pair, but interesting from the colours of its components, which are orange and blue. It will be found over the letter A in the middle of the word 'Aquarius' in the map. Below the three stars lettered ψ, and at the right angle of a rudely

Fig. 91.—107 Aquarii. Fig. 92.—P. xx. 376 Equulei.

right-angled triangle which it forms with them and δ, lies 94 Aquarii, with its gracefully contrasted colours. Lastly, reference to the map will show a little group of stars to the right of 2 Ceti. The left hand of the three contiguous ones is 107 Aquarii, which is represented in fig. 91. Here, again, varied colours come in as an adjunct to, or element in, the beauty of the object.

Over the western part of Aquarius we shall find Equuleus in the map. The second star to the right of the one marked 1 there is No. 376 of Piazzi's hour xx., which I have represented in fig. 93, and which will well repay examination. Here, again, in this pretty close pair we have to note beautifully contrasted colours. ϵ Equulei (the star marked 1 in the map), which we shall see as a double star, is really a

triple system ; but the extreme closeness of the companion of the larger star places it hopelessly beyond the reach of our aperture. λ Equulei, represented in fig. 93, is a charming and delicate pair, but quite easy to divide with our instrumental means. Both components are white.

Fig. 93.—λ Equulei.

Fig. 94.—51 Piscium.

Fig. 95.—65 Piscium.

Adjoining Equuleus to the east is the large constellation Pegasus. 1 Pegasi, bordering on Vulpecula, is a very wide pair. It is inserted here for the finely contrasted colours of its components. If we join ε Pegasi and δ Equulei by an imaginary line, and consider this as the base of a very squat triangle having its apex to the north, then at this apex will be found 15 Messier Pegasi, a fine object, presenting the appearance of a bright nebula, with marked central condensation. It is really a brilliant cluster of stars, but a three-inch telescope is quite impotent to resolve it. ε Pegasi is a very wide triple, but the colours render it interesting. κ Pegasi will tax both the eye and the instrument of the student severely. In fact, to see the minute comes at all he must remain in the dark for some little time, and even then he will only glimpse it 'out of the corner of his eye.' It is some 12″ from its primary, below and to the left of it. I cannot give a diagram of it to scale, inasmuch as the minute star would not print at all.

Bounded by Pegasus, Aquarius, Cetus, Aries, and Andromeda, is the straggling and not very intelligible constellation Pisces. If we draw an imaginary line from

γ Pegasi to η Ceti, about one-third of the way from the first-named star we shall come upon 51 Piscium, a wide but very pretty pair, represented in fig. 94. Note the lilac tint of the small companion. 55 Piscium, our next object, will be found some 7° along a line through δ and ϵ Andromedæ. The components of this charming object are very much closer than those of the previous one, being, in fact, something like one-fifth of the distance. The comes, though minute, will be detected without difficulty. About half-way between π and η Andromedæ we come upon 65 Piscium, a fine and rather close pair of very nearly equal stars. This is shown in fig. 95. ψ Piscium, the small unnamed star to the south-east of η Andromedæ on the map is another equal pair, but very considerably wider apart, and easily separable with the lowest eye-piece. ζ is also a very wide and easy star, but in this case the components are unequal. The last object identifiable from the map we are using is the leading star in the constellation, α. This fine pair is represented in fig. 96.

Fig. 96.—α Piscium.

Fig. 97.—ι Trianguli.

Before quitting this region of the sky we will just direct our instrument to that lovely little pair, ι Trianguli, which we inadvertently omitted while describing the constellation Aries on pp. 87 and 88. It is not lettered in the map to which I have so often referred, but is the star over the letter U in 'Triangula.' Its aspect is shown in fig. 97. Its finely contrasted colours are unfortunately incapable of reproduction on a wood block.

Night Nine.

Our final night I propose to devote to the circumpolar constellations, or those which wholly or in part remain always above our horizon in these latitudes. First, then, let us turn to, perhaps, the best known of them all—Ursa Major. We will begin by turning our telescope, armed with a power of 120, upon ζ (Mizar). Sharp-sighted people will detect with the naked eye a small star (Alcor) in the immediate neighbourhood of Mizar. In the telescope, with the power specified, Mizar itself will be seen to be double, and forming with Alcor the pretty triple system shown in fig. 98.

The pale green of the small star of the pair will be noted. ξ Ursæ Majoris, examined with the very highest power at the disposal of the observer, will furnish an absolutely crucial test of the excellence at once of his eye and telescope. 23 Ursæ Majoris is rather a wide pair, but interesting from the different tints of its components. 57 is a pretty pair for a similar reason, but very much closer than the last ; it is unnumbered in the map. 65, a fine triple, is also unnumbered, but may be recognised to the south of χ on the boundary of Canes Venatici. γ Ursæ Majoris lies in a fine field of stars. This constellation, I may remark, swarms with double and triple stars, but, as in a large proportion of cases they are of less than the sixth magnitude, the map takes no account of them, and it would be useless to give their co-ordinates unless the observer's instrument were equatorially mounted. Several interesting nebulæ are to be found in Ursa Major, but, in the case of the student for whom these papers are written, it can only be by fishing. If he will conceive an equilateral triangle to be described, with α and 23 Ursæ Majoris at the extremities of its base : then, by sweeping about to the right of its apex with the very lowest power he possesses, he may hit upon the two nebulæ 81 and 82 Messier, $\frac{1}{2}°$ apart. About 2° (four diameters of the moon) south-east of β is another nebula, 97 Messier, a pale circular object, looking like the ghost of a

planet. An imaginary line drawn diagonally from α through γ Ursæ, and continued nearly as far again, will strike upon ♅ v. 43, an oval nebula. Half-way, too, between β and 97 Messier lies ♅ v. 46. This will require some gazing at with so small an aperture.

And now we will direct our telescope, armed with a power of 160, to the Pole Star, which will be seen as depicted in fig. 99.

This is sometimes alleged to be a test for a three-inch telescope, but it is not so. Dawes has seen the companion with a 1·3-inch object-glass, and the eagle-eyed Ward, of Belfast, with only 1·25-inch aperture! North-west of ζ Ursæ Minoris will be found π^1, a wide and easy object.

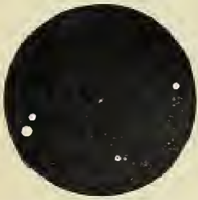

Fig. 98.—ζ Ursæ Majoris.

Fig. 99.—The Pole Star.

Fig. 100.—η Cassiopeiæ.

Cassiopeia is one of the constellations through which the Milky Way passes, and hence it affords innumerable rich fields and clusters to repay the observer who sweeps and fishes over it. γ, to begin with, lies in a fine field of small stars. η Cassiopeia, shown in fig. 100, as viewed with a power of 160, is a beautiful object, the colours being so well contrasted. ψ is a triple star, but with our optical means will only be seen as a rather wide double. σ Cassiopeiæ, to the south of β, is a beautiful, delicate, and by no means easy double star—a sort of miniature of ϵ Böotis. About κ, between γ and κ, lie some of the beautiful fields of stars to which reference has been made above.

Camelopardus contains several more or less striking pairs, but as none of them are marked in our map of reference we pass on to Lynx, where we find 38 (Map III. of

'The Stars in their Seasons'), a very close, delicate, and rather difficult pair. 19 Lyncis is a pretty triple, but it does not appear on the map.

The sprawling constellation Draco, which straggles over so much of the circumpolar sky, is our next in order for examination. From its situation the amateur can scarcely expect to scrutinise many of its chief objects in succession without getting a backache, and a stiff neck to boot, so inconveniently are they placed. Let us, however, express a hope that the intellectual pleasure to be derived from such a search may quite outweigh its concomitant physical discomfort. If we draw a line from γ Draconis, through β, and carry it on twice the distance between them, we shall strike 17 Draconis, a pretty and interesting triple. μ Draconis, a close but easy pair, is shown in fig. 101. Rather more than $1\frac{1}{2}°$ south of β Draconis is a small but very pretty double star, 147 of Piazzi's hour xvii. It is invisible to the naked eye. If we draw a line from the Pole Star to γ Draconis, and fish on it, about half-way between those stars, with a low power, we shall light upon that strange object, Herschel 37, iv. Draconis. This is the nebula which our greatest living English spectroscopist, Dr. Huggins, found to be gaseous, in 1864. Viewed in the instrument employed for the purpose of these papers, it presents the appearance of a large pale blue star out of focus. South-east of ϵ Ursæ Minoris, 40 Draconis will be found. It is a wide and easy pair. 39 Draconis, half-way between γ and δ, appears in the books as a triple star. It will require an extremely fine night and a high power, however, to show the comes to the principal star, whose light and proximity quite overpower it; so that it will ordinarily appear as a very wide double only, in a three-inch telescope. o Draconis is a wide pair, but the colours are very pretty. The last object in this constellation which we shall look at to-night, ϵ Draconis, will form a severe test, at once for the observer's instrument and his eye, and for the state of the atmosphere. He must employ the highest power at

his command, and even then the companion will often be involved in the diffraction ring surrounding the larger star. Fig. 102 gives an idea of this star when caught at moments of the best vision.

Fig. 101.—μ Draconis.

Fig. 102.—ϵ Draconis.

An examination of one more circumpolar constellation—I mean Cepheus—will complete our survey of the heavens, round the whole twenty-four hours of which we have now travelled. To begin with, the reader may find a very severe test for the light-grasping power of his instrument, and the excellence of his own eye, in 191 of Piazzi's hour ii., which lies at a distance of some 10° on a line leading from the Pole Star to β Persei. The components are close, and the observer will need a very dark night and excellent definition

Fig. 103.—κ Cephei.

Fig. 104.—ξ Cephei.

Fig. 105.—o Cephei.

to see the companion at all. κ Cephei (shown, but not lettered, in the map in an odd little corner of the constellation running into Draco) is a fine pair, which will be seen as in fig. 103. β is a wider, and also an unequal pair. In each of these cases the small star is blue. To the east-

north-east of α Cephei is a vertical line of small stars. The upper one of these is ξ, a tolerably close and somewhat unequal pair, which will repay examination. It is represented in fig. 104. δ Cephei is a beautiful object, being, as Webb says, 'something like β Cygni.' Finally we arrive at o Cephei, a very close and unequal pair, delineated in fig. 105. Both in this and δ the small stars are blue, as are, curiously, so many of the comites in this constellation.

I may say in conclusion that in these chapters I have simply endeavoured to describe a few of the chief and most easily recognisable objects on the face of the celestial vault, that are well within the optical power of a three-inch telescope. Had I been justified in assuming that all my readers were in possession of Proctor's admirable 'Star Atlas,' I might have extended my list almost indefinitely. Even as it is, I may be permitted to express a hope that I have not wholly failed in my attempt to indicate what a mine of instruction and delight lies before the possessor of even so small an instrument as that to which my descriptions have had reference.

Finally, in connection with the stellar portion of the subject, I may say here, that should any possessor of a three-inch telescope desire to verify what he may have heard or read with reference to spectrum analysis, as applied to these distant suns we have been examining, McClean's Star Spectroscope is the only one at all applicable to such an instrument as that whose employment I have presupposed. With that exceedingly ingenious little instrument the spectra of such stars as Sirius, Vega, Aldebaran, or α Orionis may be fairly well seen, even in a three-inch telescope.

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